Measuring effective coverage of facility-based childbirth care in northeast Nigeria

JOSEPHINE EXLEY

Thesis submitted in accordance with the requirements for the degree of

Doctor of Philosophy

of the University of London

MAY 2022

Department of Disease Control

Faculty of Infection and Tropical Diseases

LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE

No funding received

Research group affiliation: IDEAS Phase II Project

I, Josephine Exley, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Poor quality of care limits achieving better outcomes in maternal and newborn health (MNH). To ensure greater accountability for high quality care, effective coverage measures are now recommended. Despite global agreement on the need to apply an effective coverage cascade, operationalising the cascade is problematic and the development of actionable methods have been identified as a research priority.

This PhD investigated how effective coverage cascades can be operationalised for childbirth care using data from Gombe state, northeast Nigeria.

A systematic review examined how effective coverage measures have previously been defined. The review highlighted a lack of harmonisation and identified only one study which used routine data derived from health management information systems.

Subsequently, a cascade was developed for childbirth care by selecting the most frequently cited items from the literature that were also recommended by WHO. The PhD applied this definition to examine the extent to which meaningful effective coverage measures can be constructed from routinely available data sources in Gombe. Linking representative population data to facility data from DHIS2 it was feasible to construct a partial effective coverage measure. Compared to a gold standard measure - constructed using comprehensive health facility data – the analysis resulted in the same conclusion that effective coverage was very low.

The analysis identified a vital gap in our ability to accurately measure all steps of the cascade using routinely available data in this setting. This is problematic, given the in-depth analysis of observations of childbirth care undertaken in this PhD revealed few women received the recommended routine processes of care. Extending routine data beyond inputs requires greater advocacy to promote the value of process of care indicators for decision making. Finally, this study identified challenges in assessing inequalities in effective coverage where relying on summarised health facility data, that warrant further consideration by the measurement community as we continue to promote the use of effective coverage measures.

Acknowledgements

I have been supported throughout this PhD by a great many people. Firstly, I would like to thank my supervisors Tanya Marchant, James Hargreaves and Zelee Hill. Throughout they have provided constant support and insightful comments. I would especially like to thank Tanya Marchant for always pulling me out of the rabbit hole but also for her patience in listening as I talked myself into it! This PhD would not have been possible without her endless encouragement and guidance.

I would like to thank the members of the IDEAS team for their help, advice and friendship, especially Emma Beaumont, Antoinette Bhattacharya, Krystyna Makowiecka, Joanna Schellenberg, Noreen Seyerl, Nasir Umar, Deepthi Wickremasinghe, Barbara Willey and Suzanne Welsh. They have been the most supportive colleagues; from whom I have learnt so much.

I am also indebted to those I have been fortunate enough to collaborate with. In particular, I would like to thank Prateek Gupta, Claudia Hanson and Abdulrahman Shuaibu.

It has been a privilege to have been involved in the Gombe maternal and newborn health partnership and to be able to spend time alongside the many colleagues in Gombe who work so hard to improve the quality of care for women and their children. I would especially like to thank the Gombe State Primary Healthcare Development Agency and Data Research and Mapping Consult, in particular Adamu Umar Usman.

I would like to thank my parents who have unwaveringly supported me throughout all my academic travails. And finally, Nicky, who has lived with me through lockdowns and the completion of this PhD – a true test of his seemingly never ending kindness – thank you.

Table of contents

Table of Abbreviations

CHAT	Child Health Accountability Tracking Technical Advisory Group
CRVS	Civil registrations and vital statistics
DHIS2	District Health Information Software 2
DHS	Demographic and health surveys
IDEAS	Informed Decisions for Actions to improve maternal and newborn health
LGA	Local government area
MDG	Millennium Development Goal
MICS	Multiple Indicator Cluster Survey
MNCAHN	Maternal, newborn, child, and adolescent health and nutrition
MNH	Maternal and newborn health
MoNITOR	Mother and Newborn Information for Tracking Outcomes and Results Technical Advisory Group
NDHS	Nigerian demographic and health survey
PHC	Primacy healthcare clinic
PNC	Postnatal care
RMNCAH+N	Reproductive, maternal, newborn, and child health and nutrition
SARA	Service availability and readiness assessment
SDG	Sustainable Development Goal
SPA	Service Provision Assessment
UHC	Universal health coverage
WHO	World Health Organisation

Glossary of terms

The Agency	The Gombe State Primary Healthcare Development Agency, who are responsible for the planning and delivery of health services in Gombe State. The Agency leads the Gombe partnership.
Coverage cascade	Health-service coverage cascade recommended by the Effective Coverage Think Tank Group in the Lancet Global Health paper authored by Marsh et al. 2020.
Effective Coverage Think Tank Group	A group of 98 experts in the fields of quality of care measurement, monitoring and evaluation, epidemiology, and research convened by WHO and UNICEF in 2019 to establish standardised definitions and measurement approaches for effective coverage for MNCAHN.
Gombe Partnership	Led by the Gombe State Primary Healthcare Development Agency ('the Agency'), a health systems strengthening intervention implemented between 2016 and 2019 in Gombe. The Agency coordinated multiple actors, with the aim of equitably improving maternal and newborn health services.
Process-quality	Quality of care is a multidimensional concept, and the steps of the coverage cascade are intended to capture the different dimensions: step 3 inputs, step 4 interventions, step 5 quality, step 6 user-adherence and step 7 outcomes. In this thesis I refer to step 5 as 'process-quality' to differentiate between the specific step of the cascade and the wider conceptualisation of quality as defined in the literature.

Introduction

1 Background

Maternal and newborn health (MNH) is a key priority for the global health and development agenda. Maternal and newborn deaths are mostly preventable as the interventions needed to prevent or manage complications are known (1, 2). However, maternal and newborn deaths remain unacceptably high: every day approximately 810 women die from preventable causes related to pregnancy and childbirth, almost 7,000 newborns die and more than 7,000 newborns are stillborn (3, 4). The global burden of maternal and newborn mortality is disproportionally concentrated in sub-Saharan Africa and South Asia, and a few countries, including Nigeria and India, bear the largest proportion of deaths. Achieving reductions in maternal and newborn mortality requires improvements in both accessibility and quality of, effective interventions (5).

Efforts to improve MNH globally have been supported by the setting and measuring of goals: first the Millennium Development Goals (MDGs 4 and 5) from 1990 to 2015, followed by the Sustainable Development Goals (SDG 3) for the period 2016 to 2030 (6). The relevant targets in both the MDGs and SDGs focus on mortality: SDG 3.1 and 3.2 aim to reduce the global maternal mortality ratio to less than 70 per 100,000 live births and neonatal mortality to at least as low as 12 per 1,000 live births by 2030 (7). To track progress and performance a set of indicators that measure individuals' 'contact with' or 'access to' the health system have been adopted by global monitoring frameworks such as Countdown to 2030, the Global Strategy for Women's, Children's and Adolescents' Health 2016–2030 and the Every Newborn Action Plan (6, 8-11). These include the proportion of individuals who had: at least four antenatal care visits, a skilled attendant at birth and received postnatal care for mothers and newborns within 48 hours following birth.

Access to antenatal care and skilled birth attendance has substantially increased, however in low- and some middle-income countries these increases have not been accompanied by the anticipated improvements in MNH outcomes (12-17). This discrepancy points to a gap in the quality of care received by women and their newborns, limiting opportunities to improve the health of mothers and their babies (12, 18-20). Indicators that focus only on contacts between women and/or newborns and the health system are likely overstating the health

benefits of a programme as they take no account of the content or quality of care delivered (21-24).

To support the SDGs agenda, advancements in measurement are needed, moving beyond 'crude coverage', defined as:

"the proportion of individuals who need an intervention who actually receive it"

towards 'effective coverage' that accounts for the quality of care delivered and their impact on people's health and experience of care (25, 26). Effective coverage has been recommended by both the World Health Organisation (WHO) and the Lancet's High Quality Health Systems Commission as the preferred measure to assess health system performance (5, 27).

In the rest of this introductory chapter I outline the development of effective coverage and present a hypothetical health service coverage cascade, which has recently been proposed as the ideal method for measuring effective coverage of maternal, newborn, child, and adolescent health and nutrition (MNCAHN) (28). Finally, I consider the outstanding challenges of measuring effective coverage of childbirth care and present the research gap that this PhD aims to address.

1.1 Development of effective coverage measures in maternal and newborn health care

While the concept of effective coverage first appeared several decades ago, there is no consensus on its definition or methodological approach to its measurement. Notably definitions have been applied at the individual, population and the health system-level. Common to all approaches is that effective coverage is a multi-faceted construct that aims to capture both service contact and some measure of the quality of care received. Before introducing the Effective Coverage Think Tank Group's proposed health-service coverage cascade (28), which is used as the conceptual framework for this PhD, I provide an overview of key developments in effective coverage measurement of MNH. The use of effective coverage measures is not unique to the field of MNH and I return to the wider implications for fields beyond MNH in the discussion chapter.

The Tanahashi framework published in 1978, first proposed effective coverage as the final stage of service provision after availability of health services, physical accessibility to services, acceptability by those in need, and actual use of the service (29). In 2001, the WHO's Cluster of Evidence and Information for Policy held a technical consultation on effective coverage in health systems in Rio de Janerio, Brazil (27, 30). The background paper defined six different aspects of coverage, which could be analysed to determine where

problems lay in achieving effective coverage (Table 1-1-1). In this way, they were interested in not only the extent of effective coverage but also in examining the causes of insufficient coverage. The background paper defined effective coverage as *"the proportion of the population in need of an intervention who have received an effective intervention"*, during the meeting participants recommended effective coverage be defined as (27):

"the proportion of people for whom the health intervention had actually produced a desirable health outcome"

At the meeting, participants recommended introducing an equity dimension to examine the distribution of coverage with effective interventions by different socioeconomic groupings, recognising that coverage of many interventions tend to be systematically poorer in those with lower socioeconomic status.

Table 1-1 Six different aspects of coverage identified by the WHO working paper in 2001

Aspect	Definition
Availability coverage	The proportion of people for whom sufficient resources and technologies have been made available. The ratio of resources to the total population in need. The proportion of facilities, which offer specific resources, drugs, technologies etc.
Accessibility coverage	The proportion of people for whom health services are accessible in terms of their distance or travel time.
Acceptability coverage	The proportion of people for whom interventions are acceptable (cultural acceptability, beliefs, religion, gender etc.).
Affordability coverage	The proportion of people for whom health services are affordable.
Contact coverage	The proportion of the population that has contacted a health service provider.
Effective coverage	The proportion of the people who have received effective interventions.

In 2005, Shengali et al. defined effective coverage for an individual as (31):

"the fraction of maximum possible health gain an individual with a health care need can expect to receive from the health system"

The definition combines three components of health care service delivery into a single measure: need, use and quality (Table 1-2). While contact coverage represents the proportion of individuals who need an intervention that use it, effective coverage adjusts for the quality of the intervention received (25, 32).

Table 1-2 Effective coverage framework (31, 33)

Component	Definition
Need	Whether an individual would benefit from receiving a specific health intervention. Individuals need a health intervention if their expected health gain from receiving it is greater than zero. Need is not simply those who demand a service, but a true population measure of those who would benefit from an intervention, might be defined based on belonging to a specific group e.g. pregnant women or based on the presence of a disease/condition e.g. eclampsia.
Use	An individual, conditional on needing the intervention, received or used a specific intervention. Use will be determined by a number of factors including, perceived need, distance, price, opportunity cost of seeking care, cultural acceptability, perceived quality of a provider and the individual's economic status.
Quality	Whether a specific intervention actually conferred the health gain or protection it was supposed to (effectiveness).

In 2019, the Countdown Coverage Technical Working Group proposed a generic health service coverage cascade for reproductive, maternal, newborn, and child health and nutrition (RMNCH+N) as an organising framework for measurement of effective coverage at the population level (21). The coverage cascade outlines a series of sequential steps that the target population is anticipated to have to move through to achieve the intended health benefit, see Figure 1-1. The proposed coverage cascade approach was supported by the Effective Coverage Think Tank – a group of experts convened by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) in 2019 to establish standardised definitions and measurement approaches of effective coverage for MNCAHN (28). The Think Tank Group recommended effective coverage be defined as:

"the proportion of a population in need of a service that had a positive health outcome from the service"

Figure 1-1 Countdown Coverage Technical Working Group's hypothetical cascade of the potential losses of health benefits of interventions among a population in need of a specific health service

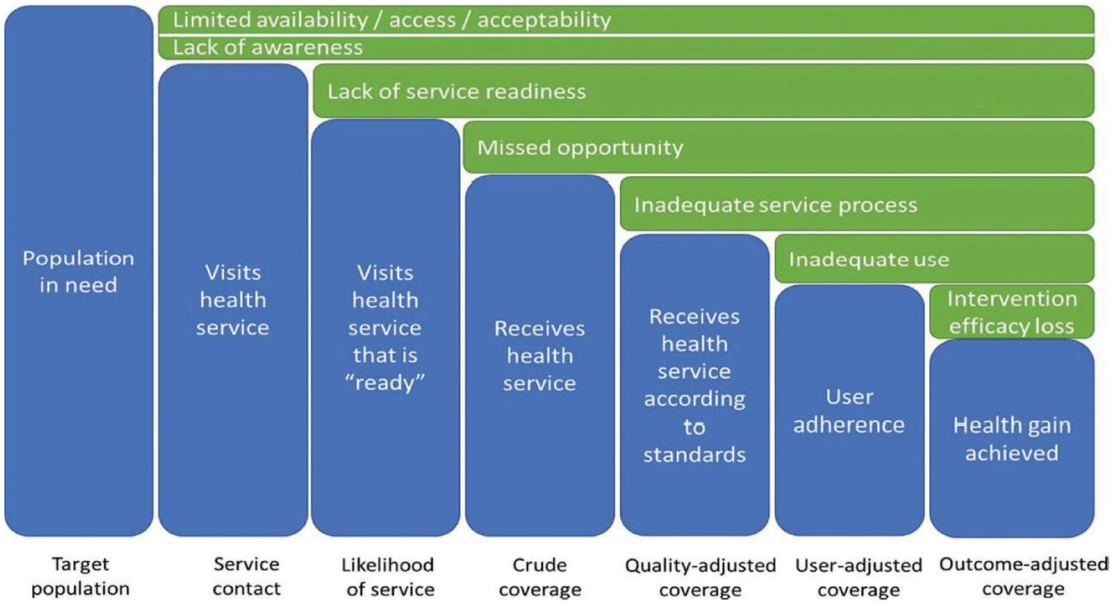


FIGURE NOTE: taken from Amouzou et al. (21)

1.2 The Think Tank Group's framework for measuring effective coverage for routine childbirth care

Figure 1-2 presents an illustrative coverage cascade through to outcome-adjusted coverage for routine childbirth care (28). The cascade starts with clearly defining/identifying the target population (the number of people with a specific health need or condition) and moves through successive steps including measuring the proportion of the target population who come into contact with the service (service contact), that is 'ready' to deliver the service e.g. drugs, equipment, adequate staff in place (input-adjusted coverage) and who receive appropriate and timely care (intervention coverage), according to quality standards (referred to in this thesis as process-quality adjusted coverage), where users adhere to prescribed medication(s) or instructions given by the care provider (user adherence adjusted coverage) and experience the expected health outcomes (outcome-adjusted coverage).

In general, this cascade is defined with each step being conditional on the previous one having been met and only the population remaining at the end of all the steps would be anticipated to have received effective coverage. In reality the cascade will look different depending on the service being provided: in particular, progression across these steps is different for promotive and preventive services compared to curative services. For example, childbirth care includes all pregnant women in the target population and integrates a package of diverse interventions to avoid potential complications and ensure a positive childbirth experience. However, even if not all components of care are received some

women and their newborns will still experience a positive outcome (healthy mother and newborn), making outcome-adjusted coverage challenging to estimate directly. Conversely curative care, such as treatment of complications e.g. pre-eclampsia, should only include symptomatic women in the target population and have a more clearly defined pathway between receipt of the intervention and health outcome. In practice, therefore, quality-adjusted coverage is likely to be the preferred measure of effective coverage of routine childbirth care.

Figure 1-2 Health service coverage cascade for routine childbirth care

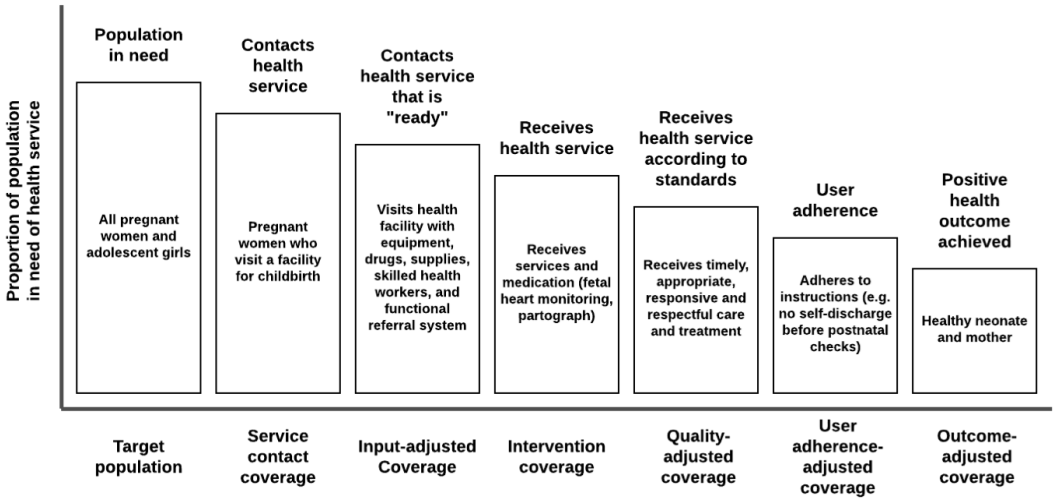


FIGURE NOTE: taken from Marsh et al. (28)

The coverage cascade can be used to inform decision makers at the: (i) programme level where bottlenecks in service provision may have occurred; and (ii) national and global level to benchmark progress against SDGs, for example. In a bottleneck analysis the relative size of the population lost at each step of the cascade is estimated to indicate where the most urgent action is needed. Where gaps exist, additional research may be needed to investigate the reason for the gap. For benchmarking, the final step (outcome-adjusted or quality-adjusted coverage) is presented as a standalone measure (composite score of effective coverage), without providing a breakdown by steps of the cascade.

1.3 Challenges with measuring effective coverage of routine childbirth

While there is a growing consensus that effective coverage for MNCAHN is best explained using coverage cascades applied at the population level, there are few examples of how effective coverage cascades can be operationalised in priority countries. Challenges remain in operationalising the cascade; primarily defining the content of the steps along the cascade, data availability and examining inequalities (28).

1.3.1 Defining the content of the cascade steps

There is no standardised list of indicators for measuring the quality of maternal and newborn care (9, 23, 34, 35). Quality of care is a multi-dimensional concept and good quality of care during childbirth in health facilities can be measured in terms of inputs (e.g. adequacy of facilities, equipment and resources), processes (e.g. appropriate use of effective clinical and non-clinical interventions, optimum skills of health provider) and outcomes (e.g. avoidable mortality and morbidity) (36). Increasingly there is a focus on a patient-centred approach, which also considers the experience of care and women and their newborns right to be treated with respect (5, 37). The WHO's 2016 framework for high quality maternal and newborn care (Figure 1-3) identifies eight 'domains' of high quality care across two inter-linked dimensions of the process of care: (i) provision and (ii) experience of care (38). In MNH, quality has most often been defined in terms of content of service and the extent to which services were delivered according to standards (21). However substantial variation in definitions exists.

Figure 1-3 WHO framework for the quality of maternal and newborn health care

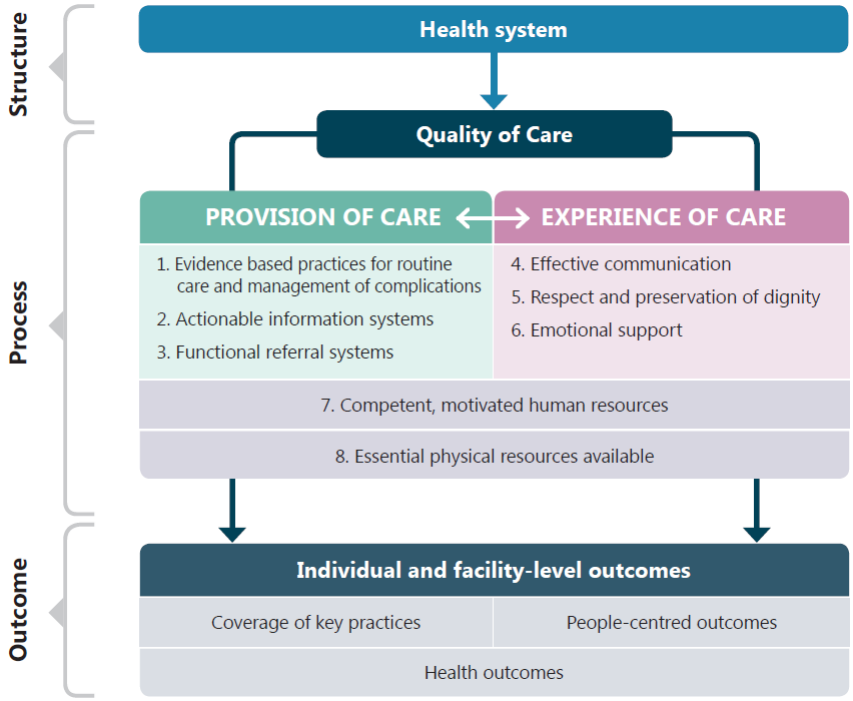


FIGURE NOTE: taken from WHO's Standards for improving quality of maternal and newborn care in health facilities (38)

1.3.2 Data availability and linking data sources

Different data sources are required to calculate the different steps of the coverage cascade for childbirth care. For example, census, civil registrations and vital statistics (CRVS) and nationally representative household surveys to determine the number of people in need of a service; health facility data from health management information systems (HMIS) and health

facility assessments, on availability of supplies and to know how well health providers function. Because of the limited validity of women's reports on clinical care provided during childbirth, direct observations of care are considered the gold standard for assessing dimensions of process of care (39-42). However, observations are time and resource intensive and there is limited availability of this data beyond small-scale primary studies. Data on some dimensions of process of care has been measured in nationally representative surveys such as service provision assessment (SPA) and service availability and readiness assessment (SARA); although neither include observations of childbirth care as standard, instead relying on healthcare workers reports of actions taken to assess process of care (43-50). There is limited evidence of routine health information systems data being used to generate effective coverage measures (51).

Where multiple data sources are used these need to be linked. Linking methods include an exact matching or individual-linking approach, linking household data to information from the precise health facility were individual survey respondents received care (52, 53) and ecological-linking approach, linking household data to summary health facility data, for example from the nearest health facility to the household cluster, or taking an average quality of care across facilities within a certain geographical distance of the facility, or making adjustments for the level of health facility that survey respondents say they accessed (45, 54-57). There is an emerging body of research comparing different linking methods (45, 50, 53, 58-60), which consistently demonstrates that ecological linking methods can generate valid measures of effective coverage. Ecological linking methods that adjust for the type of facility that women reported receiving care from have been found to give reasonable approximations to measures derived through exact matching as the quality of care was found to vary between different types of facilities but be relatively similar within facilities of the same type (53, 58, 60).

1.3.3 Measuring inequalities in effective coverage

Universal health coverage (UHC) means that high quality interventions and services are available to every person without facing discrimination or financial hardship, and achieving UHC is one of the SDG targets (61-63). Monitoring inequalities is of critical importance to support the UHC agenda of "leaving no one behind". As such, effective coverage measures should be disaggregated by key socio-demographic and economic variables(28) - such as wealth, age, ethnicity, gender, education, geography (64). Currently examples of equity analysis and guidance tend to focus on inequalities in crude coverage, typically using household data only (63, 65-69).

2 Aims and objectives

To date, discussions regarding the coverage cascade for childbirth care have been largely conceptual and questions remain over how the cascade should be operationalised, including defining the content and data source for each step (28). The majority of work undertaken has focused on antenatal and sick child care. The Effective Coverage Think Tank Group identified the following research priorities:

1. More efficient use of traditional data sources is required while also considering the potential for alternative data sources.
2. New approaches are required to improve the availability and quality (e.g. validity and reliability) of the data for measuring each step of the cascade
3. To understand the linkages between the steps in the cascade – defining the subset of activities most linked with a health outcome.
4. To ensure that the proposed effective coverage cascade is responsive to the needs of decision-makers and provide actionable information at the global, regional, national, and subnational levels
5. To determine what tools and capacity strengthening are needed within countries to collect, analyse and use these data.
6. Testing to further refine both the effective coverage indicators and cascade steps and to assess feasibility of measurement. As possible, these studies should assess inequalities in effective coverage by stratifying on key demographic variables.

The overarching aim of this PhD is to contribute to the ongoing development of measures of effective coverage by operationalising the proposed effective coverage cascades for facility-based childbirth care using data from Gombe State, in northeast Nigeria. Specifically, my PhD aims to make a contribution to the Think Tank's research priorities 1, 4 and 6.

2.1 Objectives

My PhD had four specific research objectives, each linked to a manuscript:

1. To appraise the quality of care provided to newborns and women in Gombe during childbirth and the immediate postpartum period.

2. To develop a comprehensive coverage cascade for facility based childbirth relevant to the Gombe partnership.
3. To examine the extent to which meaningful effective coverage measures can be developed from data sources that are routinely available to decision makers in low resource settings.
4. To analyse inequalities in effective coverage.

2.2 Scope of the PhD

This PhD focuses on childbirth care for women who did not experience a complication or adverse event during childbirth and the immediate postpartum period. In line with the WHO's recommendations on intrapartum care for a positive childbirth experience, it considers the routine care that all healthy women and their babies should receive to ensure high quality care and prevent complications occurring (70).

The management of women who develop complications during or after childbirth, or those identified with high-risk pregnancies, requires specialised care, which is dependent on the nature of the complication and/or condition (71). Consequently, the Effective Coverage Think Tank Group, proposed separate coverage cascades for routine childbirth (estimated as quality-adjusted coverage) and specific complications such as post-partum haemorrhage (estimated as outcome-adjusted coverage), see section 1.2 (28).

2.3 Structure of the document

I have undertaken this PhD by publication, the three research articles and one commentary stemming from this work have all been published (72-75). As such, this PhD is presented as a research style thesis, with each of the four results chapters presenting each manuscript in turn. Following this introductory chapter, chapter 3 provides a high-level summary of the methods to address each research objective. Finally, chapters 8 and 9 present an overarching discussion bringing together the different strands of the PhD.

Methods

3 Methods

To address the aims of the PhD I undertook a secondary analysis and a systematic review, see Table 3-1. As this PhD has been undertaken by publication the methods are detailed in the manuscripts presented in each results chapter. Here, I detail the study setting, the data collection methods and the unpublished analysis undertaken as part of objective 4.

Table 3-1 Overview of data source and analytical method for each research objective

Objective	Data source	Analytical methods
1	Project data: • Five rounds of observations of childbirth undertaken in 10 PHCs between June 2016 and August 2018	Mapped content of observation checklist against recommendations for high quality childbirth. Repeat cross-sectional analysis of 50 measures of evidence-based interventions and good practice.
2	Published literature	Systematic review. Mapped existing definitions of effective coverage against the Think Tank's coverage cascade. Mapped evidence-based measures identified in literature against project data.
3	Project data: • Health facility assessment from August 2019 • Observations of childbirth from August 2019 Open access nationally representative survey: • DHS Health management information system: • DHIS2	Analysis of effective coverage.
4	Project data: • Household survey from August 2019 • Health facility assessment from August 2019 • Observations of childbirth from August 2019	Analysis of inequalities in effective coverage by socioeconomic status (SES).

3.1 Study setting

Gombe State is one of six states in northeast Nigeria, it has an area of 20,265km^2 and a population of 2,857,042 (76). Gombe is made up of 11 local government areas (LGAs) and 114 wards (equivalent to districts). About half of the population live in the State's central belt - made up of four LGAs. The majority of LGAs within Gombe are inhabited by a heterogeneous ethnic population with a mix of Muslims and Christians (77).

The northeast region of Nigeria has some of the highest maternal and newborn death rates globally, estimated at 1,549 per 100,000 live births in 2015 and 33 per 1,000 live births in 2017, respectively (78, 79). Maternal and child healthcare is predominantly delivered via a network of rural, government primary healthcare clinics (PHCs) run by Gombe State Primary Healthcare Development Agency (hereafter 'the Agency'). In 2017, 460 PHCs and 26 referral facilities provided childbirth services (80). Use of maternal health care services is relatively low in Gombe. In 2018, 46% of women in Gombe reported at least one antenatal care visit from a doctor, nurse, midwife or nurse/midwife and 28% delivered in a health facility (81). Over 70% of facility deliveries, in 2018, took place in a rural PHC (82).

Deployment and retention of healthcare workers remains a challenge across Nigeria, particularly in rural areas (83). In response to the shortage and uneven distribution of healthcare workers, under its 2014 task-shifting and task-sharing policy for essential health care services, the Nigerian government has rolled out expanded training on life saving skills and emergency obstetric and newborn care to community health extension workers (CHEWs) and classifies them as skilled birth attendants (84). CHEWs are a cadre of healthcare worker specific to Nigeria, they receive three years of training to provide routine MNH care and basic emergency obstetric and newborn care in PHCs and in the community. Table 3-2 provides an overview of the tasks that can be performed by different cadres of frontline healthcare workers attending women and their babies at PHCs during childbirth and the immediate newborn period as outlined in the Task Shifting policy. In Gombe, PHCs are typically staffed with nurses, CHEWs, community health officers and junior CHEWs. PHCs are poorly resourced, often facing shortages of essential supplies and commodities to provide basic MNH care (77, 85).

Table 3-2 Recommendations for frontline healthcare workers providing labour, childbirth and immediate newborn and postnatal care

	CHEW	Nurse	Midwives	Medical Officer
Performs vaginal examination	Y	Y	Y	Y
Identifies onset of labour	Y	Y	Y	Y
Initiate and/or Continue ARV for HIV positive pregnant women	Y	Y	Y	Y
Uses partograph to monitor progress of labour, maternal and foetal well-being and takes appropriate action, including referral where required	Y	Y	Y	Y
Identifies signs of labour complications (malpresentations, prolonged and/or obstructed labour, hypertension, bleeding, and infection), performs first-line management, lifesaving procedures and ensures effective referral	Y	Y	Y	Y
Manages labour complications (malpresentations, prolonged and/or obstructed labour, hypertension, bleeding and infection)	N	N	Y	Y
Post-miscarriage: Screens women for STIs/HIV, takes first line measures and ensures effective referral	Y	Y	Y	Y
Post-miscarriage: Supports women living with HIV/AIDS, including through antiretroviral therapy	Y	Y	Y	Y
Provides supportive care including support by companion of choice	Y	Y	Y	Y
Promotes infection prevention	Y	Y	Y	Y
Provides appropriate pain relieving medication	Y	Y	Y	Y
Performs guarding of the perineum to prevent routine episiotomy	Y	Y	Y	Y
Performs episiotomy	Y	Y	Y	Y
Manages normal vaginal delivery	Y	Y	Y	Y
Performs vacuum extraction delivery	N	N	Y	Y
Performs outlet forceps delivery	N	N	Y	Y
Performs Caesarean	N	N	N	Y
Provides anaesthesia during Caesarean	N	N	N	Y
Performs AMTSL	Y	Y	Y	Y
Administers uterotonic (oxytocin or misoprostol)	Y	Y	Y	Y
Performs manual removal of retained placenta with active bleeding	Y	Y	Y	Y
Refers woman with retained placenta and no active bleeding	Y	Y	Y	Y
Performs bi-manual compression of uterus in case of uncontrolled haemorrhage	Y	Y	Y	Y
Applies an anti-shock garment in case of uncontrolled haemorrhage	Y	Y	Y	Y
Starts and maintains administration of IV fluids	Y	Y	Y	Y
Repairs episiotomy	Y	Y	Y	Y
Repairs a simple vaginal laceration	Y	Y	Y	Y
Repairs a complex vaginal laceration	N	N	Y	Y
Repairs a cervical laceration	N	N	Y	Y
Provides blood transfusion	N	Y	Y	Y
Identifies preeclampsia/eclampsia, performs first-line management and ensures effective referral	Y	Y	Y	Y
Manages preeclampsia and eclampsia	N	N	Y	Y

	CHEW	Nurse	Midwives	Medical Officer
Continue ARV for HIV positive women	Y	Y	Y	Y
Educate women on exclusive breast feeding, breast care and care of the perineum	Y	Y	Y	Y
Provides basic essential newborn care (warm, dry, wrapping, cord care)	Y	Y	Y	Y
Helps the baby breath in the first one minute from birth (use of Ambu bag with cup, Penguin bulbs syringes and mask)	Y	Y	Y	Y
Promotes initiation of breastfeeding and educate mother positioning and attachment for breast feeding	Y	Y	Y	Y
Identifies newborn complications (asphyxia, low birth weight, anomaly), performs first-line management, lifesaving procedures and ensures effective referral	Y	Y	Y	Y
Continues management of newborn complications	N	N	N	Y
Provides early infant male circumcision	N	N	Y	Y
Initiate ARV prophylaxis in HIV exposed newborn	Y	Y	Y	Y
Provide essential newborn care (immunization, Vit K, silver nitrate/TTC eye ointment, take biometric measurements)	Y	Y	Y	Y

TABLE NOTE: Taken from the 2014 task-shifting and task-sharing policy (84).

Y=yes, a recommend task. N=no, not a recommend task.

3.2 Gombe maternal and newborn health partnership

Between 2016 and 2019 the Agency led the Gombe maternal and newborn health partnership (hereafter 'the Gombe partnership') to coordinate multiple actors to implement a package of evidence-based interventions to improve access, use and quality of MNH services, across the 11 LGAs of Gombe State (86-89). The package of interventions, delivered by three NGOs (Society for Family Health (SFH), Pact's SAQIP project and Champions for Change) and funded by the Bill & Melinda Gates foundation, spanned three-interacting levels: (1) individual and family; (2) community; and (3) health system, see Table 3-3 (87-89).

At the individual and family level, interventions aimed to improve knowledge, attitudes and practices to enhance MNH home-based practices and increase demand for routine professional care; for example, a community-based Village Health Worker (VHW) home visit scheme was initiated. VHWs worked within their own community to deliver MNCH messages, encourage facility-based care, undertake basic healthcare provision including identifying danger signs and referring accordingly (90). The VHWs received four weeks' training, a stipend, uniform and job aids. The scheme also aimed to enhance links between the communities and the health system; VHWs were supervised by, and attended fortnightly meetings with, CHEWs.

At the community level, interventions aimed to improve trust and accountability between the community and the health system; for example, establishing and mentoring community-

based Mothers' Groups (91). Mothers' Groups aimed to increase uptake of MNH services, improve knowledge and attitudes towards PHCs and enhance capacity to make household decisions, including on savings and access to loans through the maternal and newborn child health Social Fund.

Interventions at the health system level aimed to improve the supply of safe, effective and high quality care; for example, working with the Agency to strengthen the supply chain for essential drugs in PHCs and the training of CHEWs in all aspects of skilled birth attendance, basic emergency obstetric care and other essential healthcare services, such that PHCs could provide basic emergency obstetric and newborn care. None of the PHCs provide caesarean sections; emergency care and complicated cases from these PHCs should be referred to referral facilities. None of the 57 PHCs have a medical doctor, 4% have at least one nurse and 19% have at least one midwife (92).

Individual/family and community based interventions were implemented in half of the state's 114 wards, purposively selected by the Agency. Within each ward one centrally located PHC was chosen to implement interventions designed to improve the quality of MNH health services. Given the high burden of maternal and newborn mortality, the Agency chose to select one PHC per ward to ensure sufficient resources could be channeled to establish one fully functioning PHC in each ward, with a view to scaling-up to the entire State over time. Additionally, a number of interventions designed to raise public awareness about MNH were implemented statewide, see Table 3-3.

Throughout implementation an adaptive management approach was taken, with all actors working together to continuously reflect on and improve implementation processes (93-95). Every six months, the Agency along with the NGOs, the Informed Decisions for Actions to improve maternal and newborn health (IDEAS) team (see section 3.3) and the Bill & Melinda Gates Foundation convened a Data Driven Learning Workshop. The workshops aimed to review progress, trouble-shoot implementation challenges, course-correct and build a common vision across participants. The workshop revolved around a Results Framework, which comprised roughly 100 indicators identified by the Gombe partnership and the Bill & Melinda Gates Foundation. Indicators covered: life-saving interventions; facility readiness for life-saving interventions; interactions between service providers and service users; quality of care; governance, knowledge, attitudes and practice; and financing for MNH. The Results Framework was populated using data generated through annual household surveys and six-monthly health facility surveys, clinical observations, facility record data extraction, NGO monitoring and special studies.

Table 3-3 Intervention components by Health System Strengthening Building Block

WHO HSS Building block	*Intervention areas only*	
Service delivery	Forum of males	A forum of males, including husbands and community and religious leaders as influencers and decision-makers, to promote maternal and newborn health messages and enhance interactions between husbands and their wives; and husbands and their mothers.
	Forum of mothers-in-law	A forum to enhance the role of mothers-in-law as influencers and decision-makers to promote key maternal and newborn health messages and health-related behaviour and to enhance interactions between mothers-in-law and pregnant/recently-delivered women.
	Mothers' groups	Establish and mentor Mothers' Groups to increase in uptake of maternal and newborn child health services, improve knowledge and attitudes towards primary health care maternal and newborn child health services and enhance capacity to make household decisions, including on savings and access to loans through the maternal and newborn child health Social Fund.
	Quality improvement teams in PHCs	Train, establish and mentor quality improvement teams in PHCs to adopt quality improvement measures and improve governance, capacity and performance of the health system.
	VHW links with facilities	Fortnightly meeting of VHWs and CHEWs – the first line of supervision – in the community, to enhance the community-facility relationship, strengthen the capacity of VHWs and enhance CHEWs' understanding of MNH related issues in the community.
Health Workforce	Financial incentives for VHWs	Performance-based financing. A system of financial incentives / rewards VHWs who complete the continuum of care in the facility. May include effective referral.
	Task shifting and training CHEWs	Training in all aspects of skilled birth attendance, basic emergency obstetric care and other essential healthcare services.
	Training and deployment of VHWs	Cadre of rural worker to visit pregnant and postpartum women in the home, facilitate and promote facility-based routine care, identify danger signs and refer for professional care, deliver maternal and newborn health messages, supply pregnancy- and delivery-related drugs.
Products & technologies	Enhancing supply chains to PHCs	Ensure reliable provision of essential maternal and newborn health commodities in PHCs to enhance quality of care. Includes bag and mask, low-cost clean delivery kits, antibiotics.
Leadership & governance	Organisational development	Training and mentoring to enhance organisational capacity, transparency and decision-making in the Agency, Local Government Authority health teams and PHCs.
	Strengthening Ward Development Committees	Ward Development Committees undertake community mobilisation and sensitisation for maternal and newborn health, support VHWs and Community Transport Volunteers, can address

		community maternal and newborn health challenges (e.g., refusal to attend antenatal care) and liaise between the community and the health facility. Train and coach Ward Development Committees to enhance performance, accountability and community participation in health systems, using community scorecards, financial management, gender audits, proposal development, maternal and newborn child health quality services etc to increase representation of women's voices and interests including access to micro-grants.
	State-wide	
Service delivery	Emergency Transport Scheme	Drivers of the Emergency Transport and Community Transport schemes are contacted by families and VHWs for transport to a facility for delivery, or in an emergency.
Information	HMIS strengthening	Data review committee, meet once a month to inspect facility data.
	Mass media events	Radio spots and leaflets to promote maternal and newborn health concepts including facility delivery.
Financing	Budget	Leveraging the State Level Accountability Mechanism to advocate for appropriate budget release for MNH

TABLE NOTE: Adapted from Willey et al. 2022 (89) and Makowiecka 2016 (88).

CHEW=community health extension worker, HMIS=Health Management Information System, MNH=maternal and newborn health, PHC=primary health clinic, VHW=village health worker

3.3 Role of the IDEAS project in the Gombe partnership

The IDEAS project is a measurement, learning and evaluation project started in 2010, with the aim of improving the health and survival of mothers and babies through generating evidence to inform policy and practice in three low-resource settings; Nigeria, India, and Ethiopia (77, 96). IDEAS' roles in the Gombe partnership included tracking progress in access to and supply of quality MNH services in the State, supporting the use of data for local decision-making within the partnership, improving the measurement of quality of care and generating knowledge on sustaining health programmes in low-income settings.

To track progress in access to, and supply of, quality MNH services in Gombe State, between 2016 and 2019 IDEAS undertook primary data collection on behalf of the Agency and its partners (77). The entire state was included in the sampling frame for this data collection, stratified into two areas: (i) 57 wards where the partnership was intensively working and (ii) the remaining 57 wards of the State. The allocation of wards to either of these two strata was purposive, decided upon by the government at the outset of the partnership. The research objectives of this PhD were not affected by this distinction and made use of data collected across the entire state. Data collected was used to track progress and fed into the Results Framework presented at the Data Driven Learning

Workshop, which together with the Agency, IDEAS co-hosted. IDEAS provided technical support to all partners in the interpretation and use of data; each Data Driven Learning Workshop was followed by a one-day practical skills session run by IDEAS. Practical skills included interpreting estimates and confidence intervals, sampling, an introduction to evaluation and data presentation.

Starting in 2017, the IDEAS project implemented an integrated data quality intervention for routine facility data, designed to facilitate existing state and district level data quality checking responsibilities and emphasise the relationship between the LGA monitoring and evaluation officers and the LGA MNH programme coordinators (39, 80, 97). The interventions included self-assessment of data quality, peer review and feedback, learning workshops, work planning for improvement, monthly state-level and LGA-level data quality summary reports, and ongoing support through Agency-approved communication channels including WhatsApp. The evaluation completed in December 2018 found significant improvements in the completeness, accuracy and internal consistency for most data elements (97).

The extensive data collected provided a unique opportunity to test and apply the coverage cascade proposed by the Think Tank Group, as a rich source of data has been collected from different sources and the quality of routine data available through District Health Information Software 2 (DHIS2) has been demonstrated to have improved.

3.3.1 My role in, and contribution of the PhD to, the IDEAS project

I worked on the IDEAS project between 2018 and 2021. My primary role was to have oversight of data collection. This included working with the measurement partners, providing technical support during and after data collection, preparing the raw datasets and the analysis of the data against a pre-defined results framework, which was shared after each data collection round with all partners. I also participated in the six-monthly Data Driven Learning Workshops, which brought all partners together to collectively share and review progress in the previous six months.

This PhD extends beyond the original objectives of the IDEAS project, which collected the data for the purpose of (i) evaluation (89), (ii) validating different data sources to measure priority indicators for MNH (39, 80), and (iii) examining respectful care (98, 99).

Whilst undertaking the systematic review component of this PhD I was connected to the Child Health Accountability Tracking (CHAT) technical Advisory Group through Professor Joanna Schellenberg (co-PI of the IDEAS study and a member of CHAT). CHAT was undertaking work to further develop the effective coverage care cascade concept and its application to monitoring progress towards child health and well-being. To support the work

of CHAT, I was asked to expand the scope of my review beyond childbirth to additionally capture interventions for children aged 1 month to 9 years.

3.4 Data collection

This PhD makes use of three of IDEAS' survey types: household survey, health facility survey and observations of births – and draws on data that would be routinely available to decision makers in this setting.

3.4.1 IDEAS project data

Between June 2016 and August 2019, an annual cluster **household survey** was conducted in 80 enumeration areas (clusters) sampled from across the 114 wards of Gombe State. Protocols were consistent with those of the Demographic and Health Surveys (DHS) (100). The same clusters were returned to each survey year. Briefly, a random sample of 40 clusters was drawn from all enumeration areas in the 57 wards where the government was intensively working and a random sample of 40 clusters was drawn from the remaining 57 wards for comparison. At each cluster, all households were listed and segmented into groups of 75 households: one segment was then selected using simple random sampling. Each of the 75 households was then invited to interview, resulting in a total of approximately 6,000 households across the 80 clusters. At each household, the household head was interviewed, a household roster completed, and every female resident aged between 13 and 49 were interviewed. Women who reported a birth in the 12 months prior to the survey were asked detailed questions about their interactions with the health system during pregnancy, childbirth and the postnatal period.

During this time, a **health facility survey** was completed every six months in a total of 97 PHCs (consisting of each of the 57 PHCs where the government was intensively working and one PHC selected at random from each of the 40 comparison household clusters) plus all 18 referral facilities in Gombe State. Survey protocols were consistent with those of the SPA (101). The health facility survey comprised a readiness assessment, data extraction from facility registers on number and outcomes of all births during previous six-months and interviews with birth attendants. The facility questionnaire included a check list of staff, equipment, drugs, and infrastructure items present on the day of survey, and data extraction from maternity registers to ascertain facility workload during the last six months. In each facility, the birth attendant interview was conducted with the frontline worker who carried out the last delivery recorded in the maternity register. The questionnaire included questions about training and supervision, routine activities carried out, availability of supplies, workload during the last month and a detailed set of questions about behaviours during the last birth they attended. In the analysis, facilities handling fewer than one delivery per week (n=11)

were excluded on the grounds that they are not representative of the typical facility women seek childbirth care.

During the six-monthly health facility surveys **clinical observations of childbirth** were completed in 10 out of the 57 PHCs where the partnership was intensively working. To achieve a sufficiently large number of observations and minimise the duration of data collection, the 10 PHCs with the highest number of births as recorded in the maternity register at the start of the data collection in 2016 were purposively selected. The mean number of births per month in the 10 PHCs was 15.7 (standard deviation [sd] 12.0), compared to 4.3 (sd 6.3) births per facility per month across Gombe State as a whole (39). Observations were completed by clinically trained female data collectors (local midwives, not employed by the facility) over a three-week period, using a structured checklist to record the processes of care and birth attendant-client interactions. The content of the checklist was developed from the USAID-funded Maternal and Child Health Integrated Program's tool for observing vaginal births and the following complications: postpartum haemorrhage, pre-eclampsia/eclampsia and newborn asphyxia (102). At each facility, we aimed to observe all women who were admitted, but prioritised observing women during the second and third stage of labour and immediately postpartum. Observers stayed continuously with women from the first point of contact until the first hour after birth. Depending on the observation team's work schedule, the first point of contact for any observation may have been during initial assessment of a newly admitted pregnant woman or at a later stage of labour. At each round of data collection we aimed to observe around 350 births. Before discharge, exit interviews were also completed with observed women who had a healthy newborn at the time of discharge.

3.4.2 Routinely available data

To reflect household survey data that is typically available to decision makers at sub-national level, I accessed the Nigerian Demographic and Health Survey (NDHS) which provides state level tabulations and was last conducted in 2018. Neither a SPA nor a SARA have been completed in Nigeria, instead the quality of care analysis drew on monthly reports from DHIS2.

The **NDHS** is conducted every five years using a two-stage stratified cluster sample, designed to be representative at the national and state level (103). The household survey included face-to-face interviews with all women aged 15 to 49 years in the sampled households, both permanent residents and visitors who stayed in the household the night before the survey. Data was extracted from the birth record for all women in Gombe State aged 15 to 49 who reported a live birth and the place of care seeking in the five years preceding the survey. The decision was taken to include all women with a live birth in the

last five years as restricting the data to more recent time-periods resulted in a small sample size: 284 reported a live birth in the preceding 12 months, 387 in last three years vs. 822 in the last five years. The number of women reporting a facility-based birth was relatively constant across time periods - 27% among women who reported a live birth in the last 12 months compared to 31% of women who reported a live birth in the last three years and 30% of women who reported a birth in the last five years – so the finding of low contact is not just a consequence of the timeframe selected.

DHIS2 is an open source health management software platform used in more than 70 countries (104). In Gombe, the services provided by health facilities are typically documented in 13 paper-based registers (80). Every month, a subset of data in these registers are tallied and summarised in a paper-based report, which is sent to the LGA health office to be entered into DHIS2. DHIS2 contains monthly reports from approximately 615 public and private health facilities in Gombe State. Monthly aggregated DHIS2 data related to MNH were downloaded for the same 6-month period as the project data, from January to July 2019. As with the project data, facilities that recorded fewer than one delivery per week on average were excluded.

3.5 Analysis

The analytical methods for objectives 1 to 3 are reported in the manuscripts, presented in result chapters 4 to 6, and so I do not repeat the methods here. For objective 4, however, the analysis of inequalities was exploratory and has not been published; the methods are described below.

As a starting point to examining inequalities in effective coverage under objective 4 I aimed to disaggregate the effective coverage cascade by relative socioeconomic status (SES). Wealth quintiles of relative SES between households was constructed based on housing characteristics (wall, floor and roof material, sanitation, electricity, water source and clean fuel) household assets ownership (fridge, television, lamp, watch, motorbike, generator and fan) using principal component analysis (105).

I used the detailed IDEAS project household and linked facility datasets and applied to cascade as defined in objective 3. The cascade was elaborated as follows:

- The target population was all women with a live birth in the last 12 months preceding the household survey.
- Contact coverage was defined as women who reported giving birth in a health facility.
- Input coverage was estimated in the health facility data set calculated as having all items available and functioning on the day of the survey. All items contributed equally to the estimate.

- Intervention and process-quality coverage measures were estimated in the observation dataset, as the percentage of women who received all components of care. Missing values were classified as not having been received.

The analysis used ecological linking methods. Each woman in the household survey who reported a facility based delivery, was assigned the average input score for the LGA and the type of health facility (either PHC or referral) where they reported seeking care. No referral facilities were sampled in one LGA, consequently women who reported delivering in a referral facility in this LGA were assigned the average input score for all referral facilities across the State. Women who sought facility based care were assigned the average intervention and process-quality score across all observations. Women who reported delivering at home were assigned input, intervention and process-quality scores of 0.

From the linked dataset, each step of the cascade was calculated as the product of the prevalence of the first step and the prevalence of the proceeding step (53). Inequalities were estimated by disaggregating each step of the cascade by SES (48, 106).

3.6 Ethics

For the project data, voluntary written informed consent was obtained from all respondents interviewed/observed. This included voluntary written informed consent from every household respondent, all birth attendants interviewed and, in the observation from those women being observed. If an individual did not consent, then the interview or observation did not take place.

All potential participants were provided with a study information sheet and a consent form in Hausa. The information sheet and consent form was read exactly as written. A copy of the form was left with the participants. The form explained the purpose of the survey/observation, the risks and benefits of participating and that their participation was completely voluntary and that they could refuse to answer any questions or stop the interview/observations at any point. After reading the statement, the interviewer/observer answered any questions before seeking written consent. Respondents were required to sign to confirm that the form has been read out. In cases where respondents were not able to sign, the respondent could put a thumb print on the form and a literate witness sign to confirm that the full consent process took place. For the observations verbal consent was sought from the birth attendant.

Approval for the clinical observations of childbirth was granted based on the following safeguarding mechanisms: pre-training to ensure observers were aware of their duty of care and the presence of a clinical supervisor on site. Observers were to call for help if they judged that the client was in danger. In reality, many health facilities in this setting have only

one trained health worker available to provide care and so additional clinical help may not have been routinely available. This is one reason why the observation work was closely supervised by a clinician who was available throughout the observation field work period. However, their ability to intervene was constrained by the restriction in law that a health worker may not legally practise in a government facility without prior registration. The supervisor was therefore able to advise but not intervene. In the event that the observer judged the client to be in danger the observation activity was to immediately stop, and a report explaining the actions and decisions made was to be sent to the Agency. These women were excluded from the study. Studies using similar methods have also been conducted (107).

The NDHS is open access and free to use for research purposes; informed consent protocols were implemented as standard. Access to DHIS2 was granted by the Agency; the data accessed was summarised at the health facility level and as such it was not possible to identify any individual.

Ethical approval for this study was obtained from the Nigerian National Health Research Ethics Committee (NHREC/01/01/2007), the State Ministry of Health Gombe State (ADM/S/658/Vol. II/66) and the London School of Hygiene & Tropical Medicine (22330).

Results

4 Objective 1: analysis of observations of childbirth care

I undertook a cross-sectional analysis of observations of childbirth and the immediate postpartum period to gain an in-depth understanding of the quality of care being provided to women and their newborns in Gombe. The analysis was published in BMJ Open:

*Exley, J., et al. (2020). "Provision of essential evidence-based interventions during facility-based childbirth: cross-sectional observations of births in northeast Nigeria." BMJ Open **10**(10): e037625.*

The manuscript is presented in the rest of this chapter and the supplementary material accompanying the manuscript is presented in appendix 1.

The provision of essential evidence-based interventions during facility-based childbirth: cross sectional observations of births in northeast Nigeria

Josephine Exley[1], Claudia Hanson[1,2], Nasir Umar[1], Barbara Willey[3], Abdulrahman Shuaibu[4], Tanya Marchant[1*]

[1] Department of Disease Control, London School of Hygiene & Tropical Medicine, UK

[2] Department of Public Health Sciences–Global Health, Karolinska Institutet, Stockholm, Sweden

[3] Department of Infectious Disease Epidemiology, London School of Hygiene & Tropical Medicine, UK

[4] The Executive Secretary, Gombe State Primary Health Care Development Agency, Nigeria

Correspondence to:
Josephine Exley
LSHTM
Keppel Street
London
WC1E 7HT
United Kingdom
Josephine.Exley@lshtm.ac.uk

Word Count: 4,764

4.1 Abstract

Objectives:

To measure the provision of evidence-based preventive and promotive interventions to women, and subsequently their newborns, during childbirth in a high-mortality setting.

Design and participants:

Cross-sectional observations of care provided to women, and their newborns during the intra- and immediate postpartum period using a standardised checklist capturing healthcare worker behaviours regarding lifesaving and respectful care.

Setting:

Ten primary healthcare facilities in Gombe State, northeast Nigeria. The northeast region of Nigeria has some of the highest maternal and newborn death rates globally.

Main outcome measures:

Data on 50 measures of internationally recommended evidence-based interventions and good practice.

Results:

1,875 women were admitted to a health facility during the observation period; of these, 1,804 gave birth in the facility and did not experience an adverse event or death. Many clinical interventions around the time of birth were routinely implemented, including provision of uterotonic (96% [95%CI 93-98]), whereas risk-assessment measures, such as history-taking or checking vital signs were rarely completed: just 2% (95%CI 2-7) of women had temperature taken and 12% (95%CI 9-16) were asked about complications during pregnancy.

Conclusions:

The majority of women did not receive the recommended routine processes of childbirth care they and their newborns needed to benefit from their choice to deliver in a health facility. In particular, few benefited from even basic risk-assessments, leading to missed opportunities to identify risks. To continue with the recommendation of childbirth care in primary healthcare in high mortality settings like Gombe it is crucial that birth attendant capacity, capability and prioritisation processes are addressed.

Strengths and limitations of this study:

- This study has a large sample size; over 1,850 women were observed across five rounds of data collection.
- The relative consistency overtime and low levels of implementation of many measures suggest that any impact of being observed was minimal.
- Observers received training, used a structured checklist and were overseen by a clinical supervisor to improve the reliability of observations.
- The study protocol prioritised observation of events closest to birth, as such 40% of women were not observed during the first stage of labour.
- This study was completed in the 10 primary healthcare facilities with the highest volume of births in Gombe State and therefore results are not representative of all facilities.

4.2 Introduction

Global efforts to reduce preventable maternal and newborn mortality have focused on skilled attendance at birth. This has resulted in marked increases in coverage of births with a skilled birth attendant, mainly operationalised through childbirth in facilities. However, these increases have not been accompanied by the anticipated improvements in maternal and newborn outcomes in many low and middle income countries, [1-4] prompting a closer examination of the quality of care provided.[5-7] A growing body of evidence from low income settings highlights low provider skills and limited facility capability to provide good-quality care at birth.[1 8-10] A recent review found large declines in the proportion of individuals estimated to have skilled birth attendance when some measure of quality was taken into account.[11]

Good quality of care includes the timely and appropriate use of evidence-based clinical and non-clinical interventions that are acceptable to women.[12-14] The World Health Organisation (WHO) has developed evidence-based guidelines around intrapartum care, which have the potential to support healthcare providers to identify gaps in the quality of care and improve the provision and experience of care.[15] A continuing challenge, however, is that detailed evidence on the extent to which the recommended interventions are practised during routine childbirth in health facilities in low-income countries is scarce.[1 16] Available studies have predominantly focused on readiness for quality such as availability of drugs, supplies and other inputs, while neglecting processes of care.[16] In part, this is because these data are made available through surveys similar to the Service Provision Assessments,[17] or through routine health information systems - information sources that include very little process quality data. Household surveys, including the Demographic and Health Survey and the Multiple Indicator Cluster Survey, do not collect extensive data on the content of care during childbirth, in part because evidence suggests women's self-reports have low validity.[18 19] This lack of data on coverage of evidence-based care during childbirth impedes decision making around possible solutions. Although not a large-scale measurement solution, observations provide useful insight in to the behaviours of healthcare workers and could support strategies to improve care.

In this study of birth observations, we aimed to examine the maternal and newborn outcomes experienced by all women admitted for childbirth and postpartum haemorrhage in a sample of primary healthcare facilities in Gombe State, Nigeria. For women who had an uncomplicated labour, we evaluated the provision of evidence-based care provided to women, and subsequently their newborns, from initial assessment up to one hour postpartum.

4.3 Methods

We conducted direct observations of childbirth care in 10 primary healthcare facilities, in Gombe State, Nigeria, approximately every six months over a two-year period between June 2016 and August 2018.

4.3.1 Study setting

Gombe State is one of six states in northeast Nigeria, it has an area of 20,265km^2 and a population of 2,857,042.[20] Over 80% of the population live in rural areas and are reliant on subsistence farming as their primary source of income.[21] The northeast region of Nigeria has some of the highest maternal and newborn death rates globally, estimated at 1,549 per 100,000 live births in 2015 and 33 per 1,000 live births in 2017, respectively.[22 23]

Access to maternal healthcare services is relatively low in Gombe State. In 2018, 46% of women in the State reported at least one antenatal care visit from a doctor, nurse, midwife or nurse/midwife and 28% delivered in a health facility.[24] Over 70% of facility deliveries, in 2018, took place in a rural primary healthcare facility.[25] Recent work in Gombe on the drivers of attending a facility for childbirth found that health system conditions including availability of staff, drugs and supply, and a clean environment had the biggest influence on respondents' decision around where to give birth.[26]

Healthcare is predominantly delivered via a network of rural primary healthcare clinics run by the Gombe State Primary Healthcare Development Agency (GSPHCDA). In 2017, 460 primary healthcare clinics and 26 referral facilities provided childbirth services.[27] In primary healthcare facilities care is typically delivered by lower cadres of healthcare workers, for example, community health extension workers (CHEWS), junior CHEWS and health officers.[28 29] In response to the shortage and uneven distribution of healthcare workers, under its task-shifting and task-sharing policy for essential healthcare services, Nigeria classifies CHEWs as skilled birth attendants.[30]

Primary healthcare facilities in Gombe are poorly resourced, often lacking essential supplies and commodities to provide basic maternal and newborn health care.[31-33] Led by the Gombe State Primary Healthcare Development Agency, since 2016 intense NGO activity has been ongoing in 57 primary healthcare facilities across Gombe State, aimed at increasing the quality of care.[34 35] Interventions include training of CHEWs in all aspects of skilled birth attendance and basic emergency obstetric care, and improving the supply of essential maternal and newborn health commodities.[36] These facilities provide basic emergency obstetric and newborn care. Emergency care and complicated cases from these health facilities are referred to referral facilities. None of the 57 primary healthcare facilities have a medical doctor, 4% have at least one nurse and 19% have at least one midwife.[37]

Sampling methods have been described in detail elsewhere.[19 32] Briefly, in November 2015, 10 primary healthcare facilities were selected from the 57 facilities for an in-depth assessment of quality of care. To achieve a sufficiently large number of observations and minimise the duration of data collection, the 10 primary healthcare facilities with the highest number of births in the preceding six months, as recorded in the maternity register, were purposively selected. The mean number of births per month in the 10 primary healthcare facilities was 15.7 (standard deviation [sd] 12.0), compared to 4.3 (sd 6.3) births per facility per month across Gombe State as a whole.[19]

4.3.2 Data collection

Five rounds of data collection took place over the two-year study period. Each round lasted three weeks, during which observers aimed to collect data from a total of around 350 women. Two trained female observers (local midwives, not employed by the facility) and one clinical supervisor were assigned to each facility. Observers worked in 8- or 12-hour shifts to provide near continual data collection during the period. Depending on the observation team's work schedule, the first point of contact for any observation may have been during initial assessment of a newly admitted pregnant woman or at a later stage of labour. Observers aimed to observe all women who were admitted irrespective of the cadre of the attending healthcare worker, but they prioritised observing women during the second and third stage of labour and immediately postpartum rather than observing women earlier in the process. Observers stayed continuously with women from the first point of contact until the first hour after birth. The healthcare worker observed may have been different at different timepoints in the same facility. The clinical supervisor was always available onsite but not present in the delivery room.

A structured clinical observation checklist, administered on a Lenovo A3300 tablet using CSPro version 7.0 (United States Census Bureau and ICF Macro, Suitland, MD, USA), was used to record the processes of care and birth attendant-client interactions and client characteristics. The content of the checklist was developed from the USAID-funded Maternal and Child Health Integrated Program's tool for observing vaginal births and the following complications: postpartum haemorrhage, pre-eclampsia/eclampsia and newborn asphyxia [38]. The checklist was piloted and modified to the Gombe context.

All women attending the facility in active labour or experiencing postpartum haemorrhage were invited to participate at the time of admission. All potential participants were provided with a study information sheet and a consent form in English and Hausa. Taking care to include any support persons accompanying potential participants, the observer read the information sheet, explained the purpose of the study, the risks and benefits of participating and answered questions before seeking written consent from the woman and verbal consent

from the healthcare worker attending. Women who were not able to write their name were asked to provide a thumb print on the consent form. Participation was voluntary and participants were free to withdraw at any time.

Before each round of data collection, observers underwent four days of training on how to conduct unobtrusive observations, the safety and confidentiality protocols and how to ensure consistency of rating between observers. Throughout the observation period, clinic supervisors conducted spot checks of observers and data to provide ongoing quality assurance.

Observers were required to prioritise the safety of the mother and newborn; protocols were established on the actions to take during any life-threatening events. This included immediately stopping the observation activity and calling for the clinical supervisor who could advise the attending healthcare worker. A formal report detailing any actions and decisions made, was made available to the Executive Secretary of the GSPHCDA. Where data collection was stopped, observations were excluded from the study.

4.3.3 Defining provision of evidence-based care

For this analysis, the content of the clinical observation checklist was mapped against current recommendations for high quality mother and newborn care.[13 15 39-42] Fifty measures were identified (Box 4-1), grouped into four organising categories based on the stage of childbirth: (1) initial assessment; (2) first stage of labour; (3) second and third stage of labour; (4) immediate newborn and postpartum care.

Box 4-1 Measures of evidence based childbirth care included in this analysis

History taking and initial assessment
• Checks client card or asks client her age, length of pregnancy, and parity
• Asks whether woman has experienced any complications during current pregnancy
• If woman has had any previous pregnancies, asks about complications during previous pregnancies
• Checks client card or asks client her HIV status
• Washes his/her hands with soap and water or uses disinfectant before initial any examination
• Takes temperature
• Takes blood pressure
• Checks foetal heart rate with fetoscope/doppler/ultrasound
• Performs vaginal examination
• Encourages the women to have a support person present during labour and birth
• Explains procedures to woman (support person) before proceeding
• Asks women (and support person) if she has any questions

First stage of labour

- Partograph used to monitor labour
- Washes his/her hands with soap and water or uses antiseptic prior to any examination of woman
- Wears high-level disinfected or sterile surgical gloves
- A support person (or companion) for mother is present at some point during labour
- At least once, explains what will happen in labour to woman (support person)
- At least once, encourages woman to consume fluids/food during labour
- Drapes woman (one drape under buttocks, one over abdomen)
- At least once, encourages/assists woman to ambulate and assume different positions during labour
- Following items of equipment laid out in preparation for birth:
    - Newborn face mask size 0 or 1 and self-inflating ventilation bag (250 or 500 mL)
    - Suction bulb
    - Disposable cord ties or clamps
    - Sterile scissors or blade
    - At least two cloths/blankets (one to dry; one to cover)

Second & third stage of labour

- Assisted by more than one healthcare worker at one point during labour
- Mother gave birth in lithotomy position (on back)
- As baby's head is delivered, supports perineum
- Administers uterotonic
- Timing of uterotonic
- If care provided by a skilled birth attendant, applies traction to the cord while applying suprapubic counter traction
- Assesses completeness of the placenta and membranes
- Assesses for perineal and vaginal lacerations
- A support person (companion) for mother is present at birth

Immediate newborn and postpartum care
• Drying baby immediately after birth with towel
• Baby placed skin-to-skin with mother
• Bathing delayed for at least one hour
• Ties or clamps cord when pulsations stop, or by 2-3 minutes after birth (not immediately after birth)
• Cuts cord with clean blade or clean scissors
• Breastfeeding initiated within first hour
• Takes mother's vital signs within the first 15 minutes after birth
• Administers antibiotics to mother postpartum
• Checks baby's temperature within the first 15 minutes after birth
• Baby weighed
• Mother and newborn kept in same room after birth (rooming-in)
• Baby kept skin-to-skin for first hour
• Administers Vitamin K to newborn
• Provides tetracycline eye ointment prophylaxis
• Administers chlorhexidine to the newborn cord
• If the mother is HIV positive, administers ARVs to newborn

4.3.4 Inclusion criteria

Data from the five data collection periods were combined into a single dataset. Observations were excluded from the dataset if the woman's outcome was not recorded. For all women observed, we mapped the different pathways from admission to the facility (childbirth or postpartum haemorrhage event) to their outcome. For women who experienced an uncomplicated labour the outcome of their baby was also mapped. An uncomplicated labour was defined as a woman who was sent to the ward for recuperation or discharged home after birth and who did not experience an adverse event to her own health (referral, postpartum haemorrhage or pre-eclampsia/eclampsia) or death.

For the analysis of the provision of essential evidence based care, our population of interest was women with an uncomplicated labour and detailed information on their care and that of their newborn are included here. Women who were admitted but experienced an adverse event or death were excluded from the analysis because of their individual medical needs. For measures related to newborn care the analysis was further restricted to newborns recorded as being alive and who did not require resuscitation care or were not referred to another facility.

4.3.5 Analysis

For each measure, percent frequencies and 95% confidence intervals were calculated, adjusted for clustering by primary healthcare facility and stratified by time point using the

svyset and svy commands in STATA version 15.1 (StataCorp, 2017, College Station, TX). Results are presented graphically by time point to highlight any variability and the average across all five time points is presented in the text.

4.3.6 Ethical approval

Ethical approval for this study were obtained from the London School of Hygiene & Tropical Medicine (reference 14091) and the Health Research Ethics Committees for Nigeria (reference NHREC/01/01/2007) and Gombe State (reference ADM/S/658/Vol. II/66).

4.3.7 Patient and Public Involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination plans of our research. Observations were recorded in English and pre-testing completed in health facilities by staff.

4.4 Results

In total 1,875 women were admitted to a facility during the five observations periods. The median age of the women was 24 years (interquartile range [IQR] 20–29) and for 19% it was their first birth: median parity 2 (IQR 1–5). The median gestational age of women on admission was 39 weeks (IQR 38–39); 6% of women had a gestational age of less than 37 weeks and for 21% of women gestational age was not recorded on their client card and/or they did not know. At the start of the observation period, 11% of women were attended by a skilled birth attendant (doctor, midwife, nurse), 39% by a CHEW or junior CHEW and 50% by an ‘other’ birth attendant. ‘Other’ included environmental health officers/technicians/assistants (43%), health attendant/assistant (43%), traditional birth attendants (4%), community health officer (1%) and other (9%).

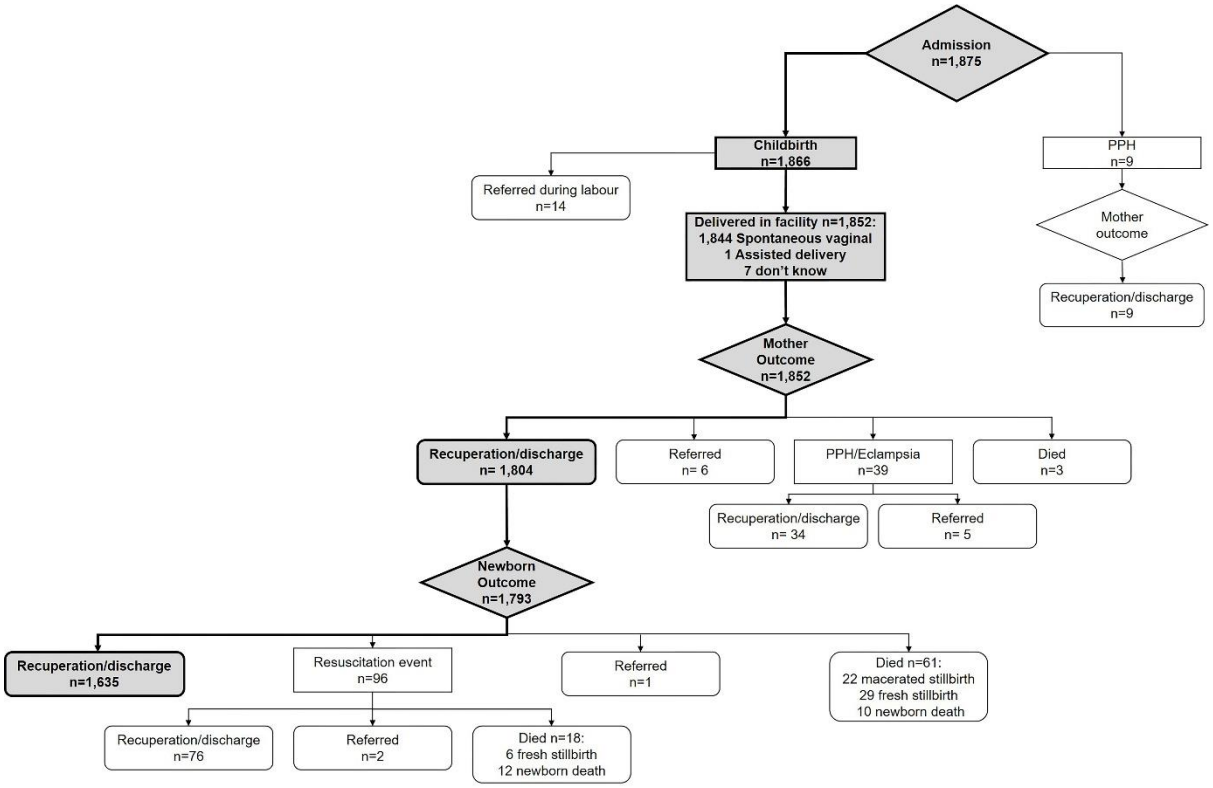
We first present the outcomes for all 1,875 women who were admitted to the facility, followed by the coverage of the provision of evidence based care measures, outlined in Box 4-1, for the 1,804 women who had an uncomplicated labour and the 1,635 babies born to these women who did not experience an adverse event or death. The full table of results disaggregated by time-point is presented in supplementary material in appendix 1.

4.4.1 Outcomes

Figure 4-1 presents the outcomes for the 1,875 women admitted to a facility during the five observation periods. Nine women were admitted with postpartum haemorrhage and 1,866 were admitted for childbirth. Fourteen women admitted for childbirth were referred to another facility during labour. The main reason for referral was prolonged labour (Panel 4-1). Of the 1,852 women who gave birth in the facility, all delivered vaginally with one woman recorded as requiring an assisted delivery; caesarean sections are not available in primary healthcare

facilities in this setting. Over half of births occurred on a weekday (56% [1,031/1,852]) between 7am and 7 pm (58% [1,067/1,852]). Two per cent (34/1,852) of deliveries were multiple births.

Figure 4-1 Women and newborn's pathway from admission



Postpartum, 45 women experienced an adverse event and three women died: the mortality rate was 1.6 per 1,000 women. Four women were referred intrapartum due to complications associated with multiple births and seven women were referred postpartum (Panel 4-1).

For the babies born to women who had an uncomplicated labour, 96 received resuscitation care of whom 19% subsequently died. Overall, 79 babies died: the perinatal mortality rate was 44.1 per 1,000 newborns (Figure 4-1). For babies born to women who experienced an adverse an event or died, 19% (9/48) were referred and four died: the perinatal morality rate among this group was 83.3 per 1,000 newborns.

Panel 4-1 Observers free text comments on reason for referral

In total 25 women were referred to another facility. Fourteen during labour - of whom one had eclampsia and three had severe pre-eclampsia; four women with multiple births were referred intrapartum; and seven were referred postpartum - of whom two had eclampsia and three experienced a postpartum haemorrhage event.

The most common reason for referral during labour was prolonged labour. One observer noted "*the mother was referred to a specialist hospital, because no progress of labour, [...] [the mother was] 4cm [dilated] after about 18 hours*" and another commented *"she was referred due to non-progress of labour despite augmentation with oxytocin*". One woman was referred because her baby was in a breech position.

For the four women diagnosed with severe pre-eclampsia/eclampsia during labour, insufficient assessment and monitoring of the woman during labour was noted: "*there were delays in needed treatment. No observations undertaken during the first hour of admission to detect disease condition and take appropriate action",* whilst another observed *"woman was admitted for normal labour but only vaginal examination was observed without physical nor vital signs or urine test".*

Five women were referred due to complications with the birth of the second twin: "*mother delivered first twin alive, mother referred […] as second twin was in transverse lie with hand prolapse"* and *"mother came with a history of twins. Delivered one at 9:48pm but the other baby refused to come out and the mother was referred in the morning around 8:39am*".

Two women with eclampsia were referred postpartum because their condition could not be stabilised. Both women experienced convulsions and lost consciousness. They both received magnesium sulphate before referral: one woman's baby was born alive and referred with the mother; the other was a fresh stillbirth.

For the three women who experienced a postpartum haemorrhage event none had severe postpartum haemorrhage (abnormal bleeding of more than 1000 mL). All received oxytocin in the facility before referral: one woman's condition was reported not to be stable and the baby required resuscitation before referral. For the other two women, who were reported to be stable, their baby was referred with them.

The remaining woman referred postpartum was referred because "*mother had a retain placenta, mentor and birth attendant tried everything but it failed*". The newborn was referred with their mother.

4.4.2 Provision of evidence-based care

All 1,804 women who had an uncomplicated labour were observed during the second and third stage of labour. Observers were required to prioritise the second and third stage of labour so the number of women and newborns observed during other stages of childbirth varied (Table 4-1).

Table 4-1 Proportion of all women admitted for childbirth who were observed, disaggregated by stage of care

Stage of care	Percentage observed	
	Women	Newborns
Initial assessment and history taking	99.8% (1,801/1,804)	n/a
First stage of labour	59.3% (1,069/1,804)	
Second & third stage of labour	100% (1,804/1,804)	
Immediate newborn & postpartum care	94.1% (1,697/1,804)	98.9% (1,617/1,635)

History taking and Initial assessment

In total, 1,801 women were observed during the initial assessment and history taking. Birth attendants were routinely observed to check the women's record for or, if not available, asked women's age, length of pregnancy and parity; 80% (95%CI 73-86), see Figure 4-2. However, other aspects of history taking including asking about complications during both

current and, if relevant, previous pregnancies were very low: 12% (95%CI 9-16) and 18% (95%CI 15-23), respectively. The most common complications that birth attendants asked about for the current pregnancy were fever (37% [81/218]), vaginal bleeding (32% [70/218]) and severe abdominal pain (25% [54/218]).

The majority of women were encouraged to have a support person present during labour and birth (63% [95%CI 53–72]). While around two thirds of birth attendants explained procedures to woman (and their support person) before proceeding (66% [95%CI 57–74]), less than a third of women (and their support person) were asked if they had any questions (32% [95%CI 25–40]).

Vaginal examination was almost universal (98% [95%CI 97-99]) but the proportion of women who had their temperature and blood pressure measured, and the foetal heart rate checked was low: 4% (95%CI 2-7), 30% (95%CI 23-39) and 22% (95%CI 16–29), respectively (Figure 4-2). Few birth attendants washed their hands with soap and water or antiseptic before examining women (28% [95%CI 21-37]).

Figure 4-2 History taking and initial examination

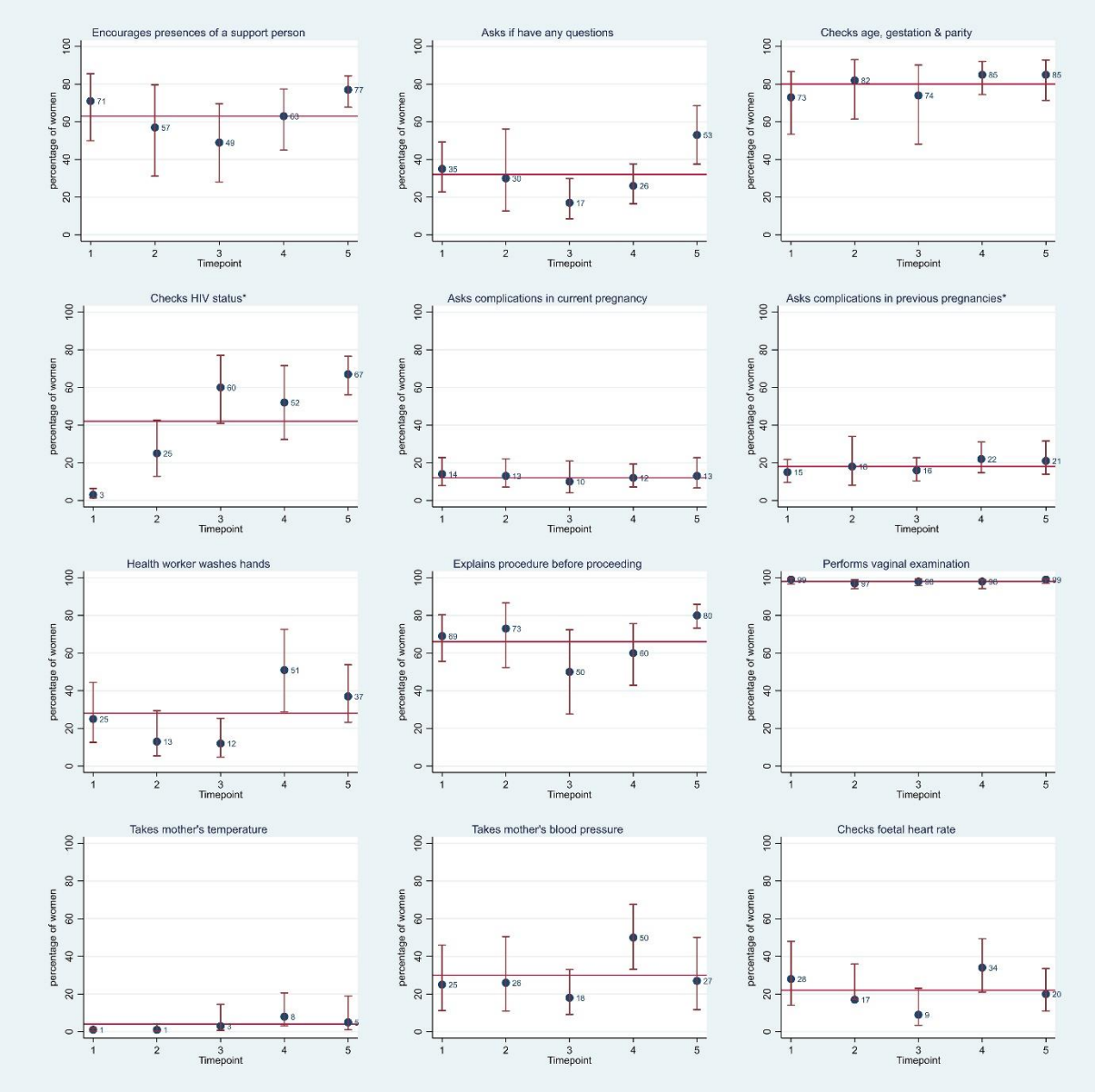


FIGURE NOTE: red line represents the average percent across all five time points. For problems experienced during previous pregnancies 10% of observers recorded that they did not know if the birth attendant asked the women. For HIV status 30% of observers recorded that they did not know if it had been checked

First stage of labour

In total, 1,069 women were observed during first stage of labour. Partograph was used to monitor labour in just 24% (95%CI 18-32) of cases (Figure 4-3). Data were not collected on whether there was a delay in the progress of labour but 17% (95%CI 12-24) of women had their labour augmented with oxytocin and 6% (95%CI 4-9) of women's membranes were artificially ruptured.

The median number of vaginal examinations undertaken during the first stage of labour was one (IQR 1-2). Birth attendants were observed to wash their hands with soap & water or use

antiseptic 39% (95%CI 30-49) of the time prior to any examination of woman, although a greater proportion were observed to wear high-level disinfectant or surgical gloves when performing the vaginal exam 76% (95%CI 64-85).

Seventy-two per cent (95%CI 63–79) of women had a support person present at some point during labour (Figure 4-3). Just under half of birth attendants were observed to explain to the woman (and their support person) what will happen during labour (49% [95%CI 42–56]). The majority of birth attendants were observed to encourage the woman to consume fluids/food at least once during labour (89% [95%CI 85-92]) and to encourage or help woman to ambulate and assume different positions (73% [95%CI 66–80]). During more than half of births observed, birth attendants were observed to drape women with a cloth, one under the buttocks and one over the abdomen (59% [95%CI 48–69]).

Data were collected on whether clean cloths/blankets, tie or cord clamp, sterile blade to cut cord, suction device and bag and mask (either size 0 or 1) were laid out in preparation for birth. Cord clamps, sterile blade and at least two cloths/blankets were available for over 90% of women (Figure 4-3). However, preparation of a bag and mask was substantially lower at 40% (95%CI 31-50).

Figure 4-3 Examinations and procedures during first stage of labour

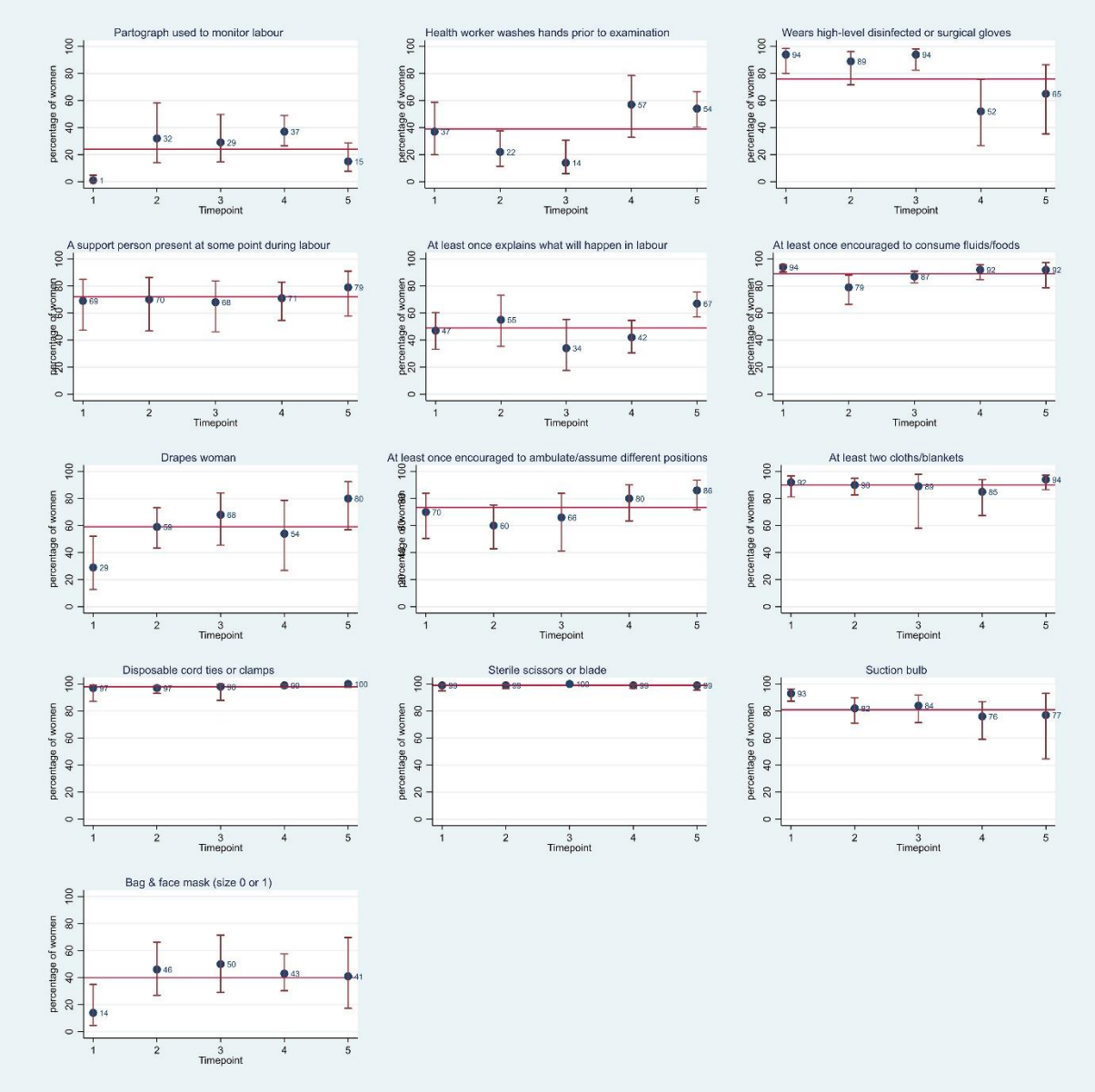


FIGURE NOTE: red line represents the average percent across all five time points

Second and third stage of labour

All 1,804 women were observed during the second and third stage of labour. Just over half of women observed were assisted at some point during the second and third stage of labour by more than one healthcare worker (57% ([95%CI 50-63]) and 36% (95%CI 27-45) had a support person present (Figure 4-4). Women universally gave birth in the lithotomy position (97% [95% CI 93-98]). The use of episiotomy was very low (1% [95%CI 1-2]). Other inappropriate practices were also low: 3% (95%CI 1-7) fundal pressure, 1% (95%CI 0-2) excessive stretching of perineum and less than 1% had lavage of uterus.

The use of prophylactic uterotonic drugs immediately after birth was universal (96% [95%CI 93-98]), and 65% (95%CI 56-73) of birth attendants checked for the presence of a second baby before administering a uterotonic. Of women that received a uterotonic, 58% received oxytocin (999/1,735) and 42% misoprostol (733/1,735). Fourteen per cent (95%CI 9-20) of deliveries where uterotonics were administered were given within 1 minute of birth and for 52% (95%CI 44-57) of women a uterotonic was administered more than 3 minutes after birth. Immediately following the delivery/expulsion of the placenta, 75% (95%CI 69-80) of birth attendants were observed to perform uterine massage.

The use of controlled cord traction was consistently undertaken by all cadres of birth attendants: skilled 91% (95%CI 83-96), CHEW 85% (95%CI 76-92) and ‘other’ birth attendant 84% (95%CI 77-89).

Following the birth of the placenta, 49% (95%CI 39-58) of birth attendants were observed to assess the completeness of placenta and membranes, a considerably higher proportion (87% [95%CI 79-92]) assessed for perineal and vaginal lacerations.

Figure 4-4 Care received during second and third stage of labour

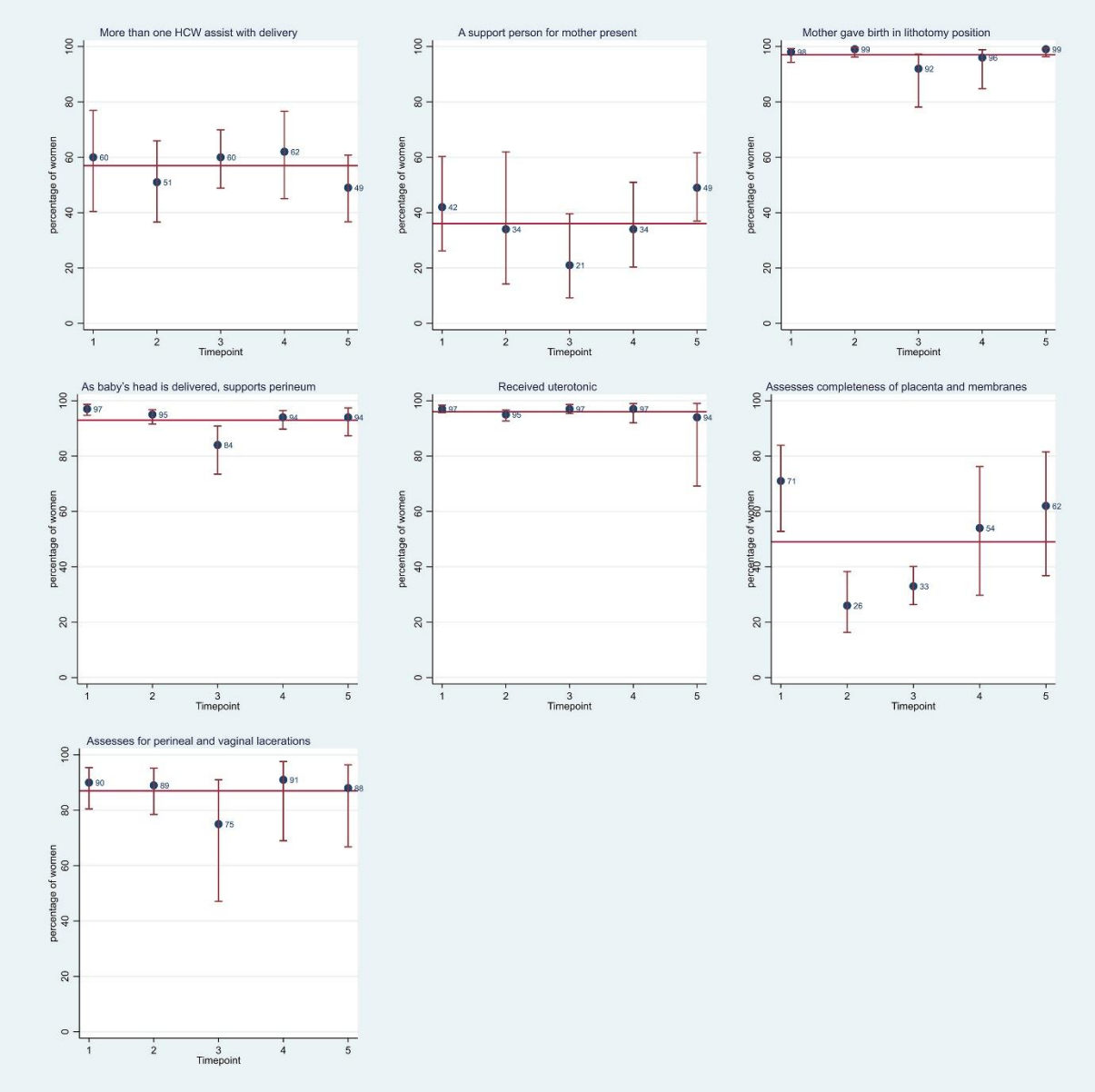


FIGURE NOTE: red line represents the average percent across all five time points

Immediate newborn and postpartum care

During the immediate postpartum period, 1,617 newborns and 1,697 women were observed. The majority of newborns received all three elements of thermal care (immediate drying, skin-to-skin and not bathing in the first hour) and clean cord care (ties or clamps cord when pulsation stop or within 2-3 minutes after birth and cuts cord with clean scissors or blade): 71% (95%CI 60-80) and 92% (95%CI 89-95), respectively (Figure 4-5). Eighty-six per cent (95%CI 75-93) of newborns had chlorohexidine applied to their cord within the first hour of birth. However, breastfeeding was initiated within the first hour after birth in just under half of newborns: 49% (95%CI 39-59).

Eighty-nine per cent (95%CI 79-95) of newborns were weighed. Of these infants, 95% (1,122/1,182) weighed more than 2.5kg (Figure 4-5). Mothers and newborns were universally kept in the same room after birth (rooming in), but only 61% (95%CI 51-71) were kept skin-to-skin during the first hour.

For the fifteen babies born to mothers known to have HIV, 33% (95%CI 14-60) were observed to receive antiretroviral therapy. The proportion of newborns on postnatal care wards who received a vitamin K injection, tetracycline eye ointment and had their temperature checked within 15 minutes after birth was close to zero throughout the study period (Figure 4-5): 0.1% (95%CI 0-0.4), 4% (95%CI 2-7) and 2% (95%CI 1-5), respectively.

Just 3% (95%CI 2-6) of women had their vital signs checked 15 minutes after birth and 2% (95%CI 1-5) of women received antibiotics.

Figure 4-5 Immediate newborn and postpartum care

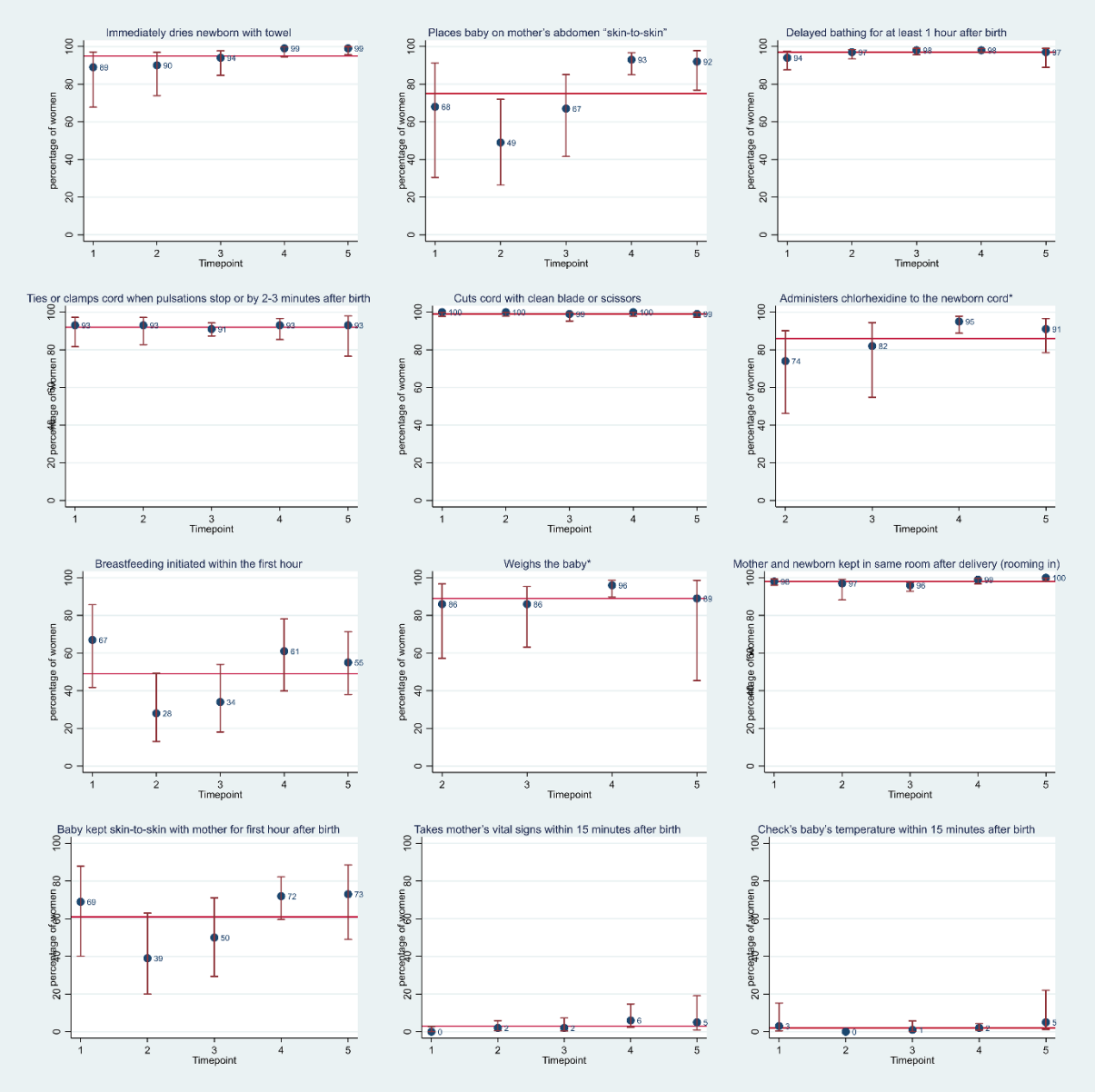


FIGURE NOTE: red line represents the average across all five time points. Administers chlorhexidine and weighs baby was not included in the checklist in the first observation period (time point 1).

4.5 Discussion

Our observations in ten primary healthcare facilities in northeast Nigeria indicated that, while some essential processes of childbirth care were performed for almost all women and newborns, the proportion of women who consistently received evidence-based care during uncomplicated labour was low. Three percent of women (48/1,852) who gave birth at the facility experienced major risks and complications while at the facility, including six severe pre-eclampsia/eclampsia and six twin deliveries. Three women died. There were large numbers of perinatal deaths and newborn referrals among this group of women. Further,

among women who we defined as having an uncomplicated labour 79 perinatal deaths were recorded, of which almost three-quarters were intrapartum stillbirths.

Our study highlights substantial variation in the implementation of recommended evidence-based interventions both within and across the different stages of childbirth: during all four stages, fewer than half of measures reached more than 80% of women. Implementation was highest for clinical interventions at the time of birth that have received international attention, for example, the provision of prophylactic uterotonic and newborn thermal and clean cord care. Implementation was lowest for measures designed as risk assessments, for example, history-taking or checking vital signs. All measures related to risk assessment during the initial assessment (asks about complications in current and previous pregnancies, takes temperature and blood pressure, checks foetal heart rate) were completed for fewer than 30% of women observed.

The evidence-based care measures included in this study were based on WHO guidelines for essential intrapartum care.[15] Their implementation should be covered in basic pre-service training for midwives, nurses and CHEWs in this setting; and they require only basic supplies of equipment. However, half of all observed births were attended by 'other' staff who would be defined as unskilled birth attendants both globally and in the Nigerian context: not doctors, nurses or midwives, nor CHEWs who have received additional training under Nigeria's task-shifting policy. Even so, far fewer than half of the women received many measures, raising questions even about the behaviours of birth attendants who have received training.[43] Further, although some variation was observed over time, in general, coverage of individual measures remained relatively constant throughout the observation period, including for a number of practices that are no longer recommended by WHO, for example, uterine massage.[44] Taken together, this study suggests that there may be limited opportunities for birth attendants to keep their knowledge up-to-date and enhance their skills once in post. Implementation research is needed to identify mechanisms to continuously support and improve healthcare worker practices, such as the use of checklists and in-service supervision and coaching, which has shown potential in other settings to improve uptake of and adherence to essential birth practices.[39 45]

A potential alternative reason for the variation in care across the continuum is that some birth attendants were working alone for extended periods. In these circumstances, birth attendants may prioritise interventions during the third stage of labour and immediate newborn care. Higher workload, as a result of staff shortages, has been found to limit healthcare workers time for history-taking, thorough assessment of women, and ability to provide timely care.[37 46] Further, when working alone, birth attendants struggle to implement multiple recommended interventions simultaneously, for example, administering uterotonic

and providing essential newborn care. While administering uterotonic was universal, less than half of women received a uterotonic within three minutes of birth. The importance of the exact timing of the application of uterotonic is not well-established, and as such, it is not clear whether this should be prioritised over immediate newborn care interventions[47 48] and clearer guidelines may be needed if it is important to prioritise certain components of care that cannot be done simultaneously by a single healthcare worker.[49]

Poor assessment of women and newborns before and after birth has previously been documented in India and other African settings.[50-52] Observations of WHO-recommended practices for screening of pre-eclampsia/eclampsia in six sub-Saharan African countries, similarly found that a low proportion of women admitted to labour and delivery services were asked about danger signs, but substantially more women (77%) had their blood pressure checked on admission.[51] Low implementation of evidence-based care measures during the initial assessment and postpartum period indicate potential missed opportunities to identify and manage complications, as evident in the referral cases (Panel 4-1). Referrals post- and intrapartum included women with high-risk pregnancies such as severe pre-eclampsia/eclampsia, breech position and twins who should have been referred to a higher level of care.[53] This study has identified proper risk assessment at the time of birth as a priority, not least because, in this setting, only 37% of women attended at least four antenatal care visits and 10% of women and 7% of newborns received a postnatal check within 2-days of birth in 2015.[54]

Poor quality of care has been acknowledged as a critical roadblock in Nigeria's attempt to reach universal health coverage. The Federal government has committed to strengthening Nigeria's health system, particularly primary healthcare, and specifically to accelerate the reduction of maternal and neonatal mortality by expanding access to, and quality of, maternal and child health services.[55] The implementation of the national strategy is supported by Nigeria's participation in the Network for Improving Quality of Care for Maternal, Newborn and Child Health (Quality of Care Network).[56] The processes of care prioritised in these strategies focus on clinical interventions at the time of birth, including use of uterotonic drugs, skin-to-skin and chlorhexidine for umbilical cord care – interventions that were found to be routinely well implemented in this low resource primary healthcare setting. This study's findings suggest if these policies are to have an impact they need to extend their focus to also include basic risk-assessment. Further, while they aim to support healthcare workers at the health facilities through quality improvement cycles, clinical mentoring and peer-to-peer learning they may also need to consider the quality of pre-service training.

Strengths and Limitations

This study provides unique insight into the provision of evidence-based practices during childbirth and highlights clear areas for action in this setting, actions that are also likely to be relevant elsewhere. A particular strength was the relatively large sample size from multiple time points although, due to the study protocol to prioritise events closest to birth, over 40% of women were not observed during the first stage of labour. The missing observations are not anticipated to impact on findings as non-observation was random, with women who were not observed during the first stage of labour unlikely to differ systematically from those who were. Being observed may have impacted on birth attendants' behaviour; evidence suggests that being observed can positively improve behaviours although any change is likely to be short lived.[57 58] The sample size was estimated to be sufficiently large to reduce the impact of any potential Hawthorne effect and the relative consistency overtime and the low levels of implementation of many measures suggest that any effect of being observed was minimal.

This study was completed in the 10 primary healthcare facilities with the highest volume of births in Gombe State and is not therefore representative of all primary healthcare facilities. It is anticipated that these facilities represent the 'best' care available at the primary level and therefore findings are likely to overestimate the provision of evidence-based care available to the wider population. These findings support the growing body of evidence that giving birth in a primary healthcare facility might not be sufficient to ensure the effective care of women and newborns,[1 4 59] and raise questions about the safety and quality of rural primary healthcare facilities that have low-volume of deliveries.[16 60]

Conclusions

The recommendation for women to deliver in health facilities is designed to improve birth outcomes. This study of clinical observations of labour and the immediate postpartum period in primary facilities in Gombe State has revealed that, while some processes of clinical care were well adhered to, most women delivering in primary healthcare facilities do not receive the complete repertoire of childbirth care that they and their newborns needed to benefit from their choice to deliver in a health facility. In particular, few women or newborns benefited from even basic risk assessments, leading to missed opportunities to identify risks and consequently late referrals and deaths. To continue with the recommendation of childbirth care in primary healthcare in high mortality settings like Gombe it is crucial that birth attendant capacity, capability and prioritisation processes are purposively addressed.

4.6 Supporting information

Acknowledgements:

The authors would like to thank Data Research and Mapping Consult for coordinating the data collection, the Gombe State Primary Health Care Development Agency, Gombe State Ministry of Health and our partners Society for Family Health and Pact Nigeria for their support in carrying out this study. We would like to thank all the participants who contributed to our study.

Ethical approval and consent to participate:

This research was conducted with approval from the Federal Ministry of Health Abuja, Nigeria, the State Ministry of Health Gombe State, Nigeria and the London School of Hygiene & Tropical Medicine (reference 12181).

Funding:

This work is part of the IDEAS (Informed Decisions for Actions to improve maternal and newborn health) project. IDEAS is funded through a grant from the Bill & Melinda Gates Foundation to the London School of Hygiene & Tropical Medicine. Gates Global Health Grant Number: OPP1149259/INV-007644. The funder had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

Competing interests:

We have read the BMJ policy and the authors declare that they have no competing interests.

Authors' contributions:

JE conducted the analysis and drafted the manuscript. CH supported the refinement of our definition of evidence-based care and reviewed the manuscript for intellectual content. NU, BW and AS all critically reviewed the manuscript for intellectual content. TM conceived the study and drafted the manuscript. All authors have read and approved the final version of the manuscript.

Data sharing:

The data are available from the principal investigator of the IDEAS project and co-author for this manuscript, Dr Tanya Marchant ORCID id 0000-0002-4228-4334. Reuse permitted on request.

Patient consent and confidentiality:

Participation in the study was voluntary and participants were free to withdraw from the study at any time without giving a reason. Researchers explained the purpose of the study and

answered any questions participants had. The free and informed consent of all women and birth attendants observed was obtained before participating.

Patient and public involvement:

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research. Observations were recorded in English and pre-testing completed in health facilities by staff.

4.7 References

1. Campbell OM, Calvert C, Testa A, et al. The scale, scope, coverage, and capability of childbirth care. *Lancet (London, England)* 2016;388(10056):2193-208. doi: 10.1016/s0140-6736(16)31528-8 [published Online First: 2016/09/20]
2. Gabrysch S, Nesbitt RC, Schoeps A, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. *The Lancet Global health* 2019;7(8):e1074-e87. doi: 10.1016/s2214-109x(19)30165-2 [published Online First: 2019/07/16]
3. Randive B, Diwan V, De Costa A. India's Conditional Cash Transfer Programme (the JSY) to Promote Institutional Birth: Is There an Association between Institutional Birth Proportion and Maternal Mortality? *PloS one* 2013;8(6):e67452. doi: 10.1371/journal.pone.0067452 [published Online First: 2013/07/05]
4. Scott S, Ronsmans C. The relationship between birth with a health professional and maternal mortality in observational studies: a review of the literature. *Tropical medicine & international health : TM & IH* 2009;14(12):1523-33. doi: 10.1111/j.1365-3156.2009.02402.x [published Online First: 2009/10/02]
5. Kruk ME, Gage AD, Joseph NT, et al. Mortality due to low-quality health systems in the universal health coverage era: a systematic analysis of amenable deaths in 137 countries. *Lancet (London, England)* 2018;392(10160):2203-12. doi: 10.1016/s0140-6736(18)31668-4 [published Online First: 2018/09/10]
6. Kruk ME, Gage AD, Arsenault C, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. *The Lancet Global Health* 2018;6(11):e1196-e252. doi: 10.1016/S2214-109X(18)30386-3
7. World Health Organization. Strategies towards ending preventable maternal mortality (EPMM). Geneva: World Health Organization 2015:44 p. Executive summary published as WHO/RHR/15.03.
8. Merali HS, Lipsitz S, Hevelone N, et al. Audit-identified avoidable factors in maternal and perinatal deaths in low resource settings: a systematic review. *BMC pregnancy and childbirth* 2014;14:280. doi: 10.1186/1471-2393-14-280 [published Online First: 2014/08/19]
9. Hobbs AJ, Moller AB, Kachikis A, et al. Scoping review to identify and map the health personnel considered skilled birth attendants in low-and-middle income countries from 2000-2015. *PloS one* 2019;14(2):e0211576. doi: 10.1371/journal.pone.0211576 [published Online First: 2019/02/02]
10. Radovich E, Benova L, Penn-Kekana L, et al. 'Who assisted with the delivery of (NAME)?' Issues in estimating skilled birth attendant coverage through population-based surveys and implications for improving global tracking. *BMJ global health* 2019;4(2):e001367. doi: 10.1136/bmjgh-2018-001367 [published Online First: 2019/05/30]
11. Amouzou A, Leslie HH, Ram M, et al. Advances in the measurement of coverage for RMNCH and nutrition: from contact to effective coverage. *BMJ global health* 2019;4(Suppl 4):e001297. doi: 10.1136/bmjgh-2018-001297 [published Online First: 2019/07/13]
12. Tuncalp, Were WM, MacLennan C, et al. Quality of care for pregnant women and newborns-the WHO vision. *BJOG : an international journal of obstetrics and gynaecology* 2015;122(8):1045-9. doi: 10.1111/1471-0528.13451 [published Online First: 2015/05/02]
13. Miller S, Abalos E, Chamillard M, et al. Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide. *Lancet (London, England)* 2016;388(10056):2176-92. doi: 10.1016/s0140-6736(16)31472-6 [published Online First: 2016/09/20]
14. Oladapo O, Tunçalp Ö, Bonet M, et al. WHO model of intrapartum care for a positive childbirth experience: transforming care of women and babies for improved health

and wellbeing. *BJOG: An International Journal of Obstetrics & Gynaecology* 2018;125(8):918-22. doi: 10.1111/1471-0528.15237
15. World Health Organization. WHO recommendations: intrapartum care for a positive childbirth experience. Geneva: World Health Organization, 2018.
16. Kruk ME, Leslie HH, Verguet S, et al. Quality of basic maternal care functions in health facilities of five African countries: an analysis of national health system surveys. *The Lancet Global health* 2016;4(11):e845-e55. doi: 10.1016/s2214-109x(16)30180-2 [published Online First: 2016/10/22]
17. The DHS Program. Service Provision Assessment (SPA) Overview.online: https://dhsprogram.com/What-We-Do/Survey-Types/SPA.cfm [accessed on 16 January 2020]
18. Moxon SG, Ruysen H, Kerber KJ, et al. Count every newborn; a measurement improvement roadmap for coverage data. *BMC pregnancy and childbirth* 2015;15 Suppl 2:S8. doi: 10.1186/1471-2393-15-s2-s8 [published Online First: 2015/09/24]
19. Bhattacharya AA, Allen E, Umar N, et al. Monitoring childbirth care in primary health facilities: a validity study in Gombe State, northeastern Nigeria. *Journal of global health* 2019;9(2):020411. doi: 10.7189/jogh.09.020411 [published Online First: 2019/07/31]
20. Gombe State Government. History of Gombe State, Nigeria. 2018;online: http://gombestate.gov.ng/history-2/ [accessed on 9 September 2019]
21. Oruonye E, Abubakar H, Ahmed M, et al. Hiv/Aids interventions in Gombe state Nigeria; challenges of sustaining the gains. *International Journal of Asian Social Science* 2017;7(6):448-57.
22. Izugbara CO, Wekesah FM, Adedini SA. Maternal Health in Nigeria. A Situation Update. Nairobi, Kenya: African Population and Health Research Centre, 2016.
23. National Bureau of Statistics and United Nations Children's Fund. Multiple Indicator Cluster Survey 2016–17, Survey Findings Report. Abuja: Nigeria National Bureau of Statistics and United Nations Children's Fund, 2017.
24. National Population Commission and ICF. Nigeria Demographic and Health Survey 2018. Key Indicators Report. Abuja, Nigeria, and Rockville, Maryland, USA, 2019.
25. Nigeria Health Management Information System. Gombe State facility deliveries, by facility type, January-December 2018. *Nigeria District Health Information System, version 2* 2019
26. Umar N, Quaife M, Exley J, et al. Toward improving respectful maternity care: a discrete choice experiment with rural women in northeast Nigeria. *BMJ global health* 2020;5(3):e002135. doi: 10.1136/bmjgh-2019-002135 [published Online First: 2020/03/24]
27. Bhattacharya AA, Umar N, Audu A, et al. Quality of routine facility data for monitoring priority maternal and newborn indicators in DHIS2: A case study from Gombe State, Nigeria. *PloS one* 2019;14(1):e0211265. doi: 10.1371/journal.pone.0211265 [published Online First: 2019/01/27]
28. Gombe State Ministry of Health. Gombe state framework for the implimentation of expanded access to family planning services. 2012;online: https://www.fhi360.org/sites/default/files/media/documents/nigeria-gombe-state-framework.pdf [accessed on 19 June 2020]
29. Gombe State Ministry of Health. Gombe State government strategic health development plan. 2010;online: https://drive.google.com/file/d/0B1DAmtM1BcbMeVBRUjNEakViXzQ/view [accessed on 19 June 2020]
30. Federal Ministry of Health. Task-shifting and task-sharing policy for essential health care services in Nigeria. Abuja, Nigeria, 2014.
31. Exley JL, Umar N, Moxon S, et al. Newborn resuscitation in Gombe State, northeastern Nigeria. *Journal of global health* 2018;8(2):020420. doi: 10.7189/jogh.08.020420 [published Online First: 2018/11/10]

32. Marchant T. Change in maternal and newborn health care. Interactions between families and frontline workers - their frequency, quality and equity - and coverage of interventions of mothers and newborns. Report from Gombe State, Nigeria, 2012-2015. online: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/08/Marchant_IDEAS_Gombe_State_Follow-upSurvey_2016.pdf [accessed on 9 September 2019]: IDEAS, London School of Hygiene & Tropical Medicine, 2016.
33. E4A-MamaYe. Gome PHC stockout of essential life-saving commodities scorecards. Jan - June 2018. 2018;online: https://mamaye.org/resources/scorecards/gombe-phc-stockout-essential-life-saving-commodities-scorecard [accessed on 20 June 2020]
34. IDEAS team. Informed Decisions for Actions in Maternal and Newborn Health 2010-17 Report: What works, why and how in maternal and newborn health. online: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/09/LSHTM_IDEAS_PhaseIReport_Web-reduced.pdf [accessed on 9 August 2019]: IDEAS, London School of Hygiene & Tropical Medicine, 2017.
35. Makowiecka K, Marchant T, Betemariam W, et al. Characterising innovations in maternal and newborn health based on a common theory of change: lessons from developing and applying a characterisation framework in Nigeria, Ethiopia and India. *BMJ global health* 2019;4(4):e001405. doi: 10.1136/bmjgh-2019-001405 [published Online First: 2019/08/14]
36. Makowiecka K. The Pathway to Improved Maternal and Newborn Health Outcomes. Use of data for maternal and newborn health in Gombe State, Nigeria. online: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/08/Makowiecka_IDEAS_Pathway_Improved_Maternal_Newborn_Health_Gombe_Nigeria_2016.pdf [accessed on 9 September 2019]: IDEAS, London School of Hygiene & Tropical Medicine, 2016.
37. Shobo OG, Umar N, Gana A, et al. Factors influencing the early initiation of breast feeding in public primary healthcare facilities in Northeast Nigeria: a mixed-method study. *BMJ open* 2020;10(4):e032835. doi: 10.1136/bmjopen-2019-032835
38. USAID. Maternal and Newborn Quality of Care Surveys. *Maternal and Child Health Integrated Program* 2013;online: https://www.mchip.net/qocsurveys/ [accessed on 10 September 2019]
39. Marx Delaney M, Maji P, Kalita T, et al. Improving Adherence to Essential Birth Practices Using the WHO Safe Childbirth Checklist With Peer Coaching: Experience From 60 Public Health Facilities in Uttar Pradesh, India. *Global Health: Science and Practice* 2017;5(2):217-31. doi: 10.9745/GHSP-D-16-00410
40. World Health Organization. Standards for improving quality of maternal and newborn care in health facilities. Geneva: World Health Organization, 2016.
41. World Health Organization. Consultation on improving measurement of the quality of maternal, newborn and child care in health facilities. Geneva: World Health Organization, 2013.
42. World Health Organization, United Nations Population Fund, UNICEF. Pregnancy, childbirth, postpartum and newborn care. A guide for essential practice (3rd edition). Geneva: World Health Organization, 2015.
43. Harvey SA, Blandon YC, McCaw-Binns A, et al. Are skilled birth attendants really skilled? A measurement method, some disturbing results and a potential way forward. *Bulletin of the World Health Organization* 2007;85(10):783-90. doi: 10.2471/blt.06.038455 [published Online First: 2007/11/27]
44. World Health Organization. WHO recommendations for the prevention and treatment of postpartum haemorrhage. Geneva: World Health Organization, 2012.
45. Semrau KEA, Hirschhorn LR, Marx Delaney M, et al. Outcomes of a Coaching-Based WHO Safe Childbirth Checklist Program in India. *The New England journal of medicine* 2017;377(24):2313-24. doi: 10.1056/NEJMoa1701075 [published Online First: 2017/12/14]

46. Munabi-Babigumira S, Glenton C, Lewin S, et al. Factors that influence the provision of intrapartum and postnatal care by skilled birth attendants in low- and middle-income countries: a qualitative evidence synthesis. *Cochrane Database of Systematic Reviews* 2017(11) doi: 10.1002/14651858.CD011558.pub2
47. Vogel JP, Williams M, Gallos I, et al. WHO recommendations on uterotonics for postpartum haemorrhage prevention: what works, and which one? *BMJ global health* 2019;4(2):e001466. doi: 10.1136/bmjgh-2019-001466
48. Bartlett L, Cantor D, Lynam P, et al. Facility-based active management of the third stage of labour: assessment of quality in six countries in sub-Saharan Africa. *Bulletin of the World Health Organization* 2015;93(11):759-67. doi: 10.2471/blt.14.142604 [published Online First: 2015/11/10]
49. Moller AB, Newby H, Hanson C, et al. Measures matter: A scoping review of maternal and newborn indicators. *PloS one* 2018;13(10):e0204763. doi: 10.1371/journal.pone.0204763 [published Online First: 2018/10/10]
50. de Graft-Johnson J, Vesel L, Rosen HE, et al. Cross-sectional observational assessment of quality of newborn care immediately after birth in health facilities across six sub-Saharan African countries. *BMJ open* 2017;7(3):e014680. doi: 10.1136/bmjopen-2016-014680 [published Online First: 2017/03/30]
51. Rawlins B, Plotkin M, Rakotovao JP, et al. Screening and management of pre-eclampsia and eclampsia in antenatal and labor and delivery services: findings from cross-sectional observation studies in six sub-Saharan African countries. *BMC pregnancy and childbirth* 2018;18(1):346. doi: 10.1186/s12884-018-1972-1
52. Saxena M, Srivastava A, Dwivedi P, et al. Is quality of care during childbirth consistent from admission to discharge? A qualitative study of delivery care in Uttar Pradesh, India. *PloS one* 2018;13(9):e0204607. doi: 10.1371/journal.pone.0204607 [published Online First: 2018/09/28]
53. Hanson C, Munjanja S, Binagwaho A, et al. National policies and care provision in pregnancy and childbirth for twins in Eastern and Southern Africa: A mixed-methods multi-country study. *PLoS medicine* 2019;16(2):e1002749. doi: 10.1371/journal.pmed.1002749 [published Online First: 2019/02/20]
54. Marchant T, Beaumont E, Makowiecka K, et al. Coverage and equity of maternal and newborn health care in rural Nigeria, Ethiopia and India. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne* 2019;191(43):E1179-e88. doi: 10.1503/cmaj.190219 [published Online First: 2019/10/30]
55. Federal Government of Nigeria. Second National Strategic Health Development Plan 2018-2022. 2019;online: http://www.health.gov.ng/doc/NSHDP%20II%20Final.pdf [accessed on 3 February 2020]
56. Network for Improving Quality of Care for Maternal NaCH. Quality of Care in Nigeria. 2019;online: http://www.qualityofcarenetwork.org/country-data/nigeria [accessed on 3 February 2020]
57. Leonard K, Masatu MC. Outpatient process quality evaluation and the Hawthorne Effect. *Social Science & Medicine* 2006;63(9):2330-40. doi: https://doi.org/10.1016/j.socscimed.2006.06.003
58. Leonard KL. Is patient satisfaction sensitive to changes in the quality of care? An exploitation of the Hawthorne effect. *Journal of Health Economics* 2008;27(2):444-59. doi: https://doi.org/10.1016/j.jhealeco.2007.07.004
59. Sharma G, Powell-Jackson T, Haldar K, et al. Quality of routine essential care during childbirth: clinical observations of uncomplicated births in Uttar Pradesh, India. *Bulletin of the World Health Organization* 2017;95(6):419-29. doi: 10.2471/blt.16.179291 [published Online First: 2017/06/13]
60. Hanson C, Schellenberg J. Redesigning maternal health services: is centralisation the answer in low-resource settings? *BMJ global health* 2019;4(3):e001488. doi: 10.1136/bmjgh-2019-001488 [published Online First: 2019/07/03]

5 Objective 2: systematic review of the content of effective coverage measures

To inform the development of a comprehensive coverage cascade for childbirth care, I undertook a systematic review to examine how previous studies had defined effective coverage, and mapped findings against the coverage cascade. As noted in the methods section 3.2.1, the scope of the review was expanded beyond childbirth care to also capture interventions of interest to CHAT.

The systematic review and mapping was published in the Journal for Global Health:

*Exley, J., et al. (2021). "A rapid systematic review and evidence synthesis of effective coverage measures and cascades for childbirth, newborn and child health in low- and middle-income countries." J Glob Health **12**.*

The manuscript is presented in the rest of this chapter and the supplementary material accompanying the manuscript is presented in appendix 2.

A rapid systematic review and evidence synthesis of effective coverage measures and cascades for childbirth, newborn and child health in low- and middle-income countries

Josephine Exley[1]*, Prateek Anand Gupta[2]*, Joanna Schellenberg[1], Kathleen L. Strong[3], Jennifer Harris Requejo[4], Ann-Beth Moller[5], Allisyn C. Moran[3], and Tanya Marchant[1] on behalf of the Child Health Accountability Tracking Technical Advisory Group (CHAT) and the Mother and Newborn Information for Tracking Outcomes and Results Technical Advisory Group (MoNITOR).

Author affiliations

1 Department of Disease Control, London School of Hygiene & Tropical Medicine, London, UK

2 Montpellier, France

3 Department of Maternal, Newborn, Child and Adolescent Health, World Health Organization, Geneva, Switzerland

4 Division of Data, Analytics, Planning & Monitoring, United Nations Children's Fund, New York, USA

5 UNDP/UNFPA/UNICEF/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP), Department of Reproductive Health and Research, World Health Organization, Geneva, Switzerland

Correspondence to Josephine Exley (Josephine.Exley@lshtm.ac.uk; London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT, United Kingdom) or Prateek Gupta (Prateek.a.gupta@gmail.com, 17 Rue Saint-Firmin, Montpellier, 34000, France)

*Joint first authors.

Word count: 4,864

5.1 Abstract

Background:

Effective coverage measures aim to estimate the proportion of a population in need of a service that received a positive health outcome. In 2020, the Effective Coverage Think Tank Group recommended using a 'coverage cascade' for maternal, newborn, child and adolescent health and nutrition (MNCAHN), which organises components of effective coverage in a stepwise fashion, with each step accounting for different aspects of quality of care (QoC), applied at the population level. The cascade outlines six steps that increase the likelihood that the population in need experience the intended health benefit: 1) the population in need (target population) who contact a health service; 2) that has the inputs available to deliver the service; 3) who receive the health service; 4) according to quality standards; 5) and adhere to prescribed medication(s) or health workers instructions; and (6) experience the expected health outcome.

We examined how effective coverage of life-saving interventions from childbirth to children aged nine has been defined and assessed which steps of the cascade are captured by existing measures.

Methods:

We undertook a rapid systematic review. Seven scientific literature databases were searched covering the period from May 1, 2017 to July, 8 2021. Reference lists from reviews published in 2018 and 2019 were examined to identify studies published prior to May 2017. Eligible studies reported population-level contact coverage measures adjusted for at least one dimension of QoC.

Results:

Based on these two search approaches this review includes literature published from 2010 to 2021. From 16,662 records reviewed, 33 studies were included, reporting 64 effective coverage measures. The most frequently examined measures were for childbirth and immediate newborn care (n=24). No studies examined measures among children aged five to nine years. Definitions of effective coverage varied across studies. Key sources of variability included (i) whether a single effective coverage measure was reported for a package of interventions or separate measures were calculated for each intervention; (ii) the number and type of coverage cascade steps applied to adjust for QoC; and (iii) the individual items included in the effective coverage definition and the methods used to generate a composite quality measure.

Conclusion:

In the MNCAHN literature there is substantial heterogeneity in both definitions and construction of effective coverage, limiting the comparability of measures over time and place. Current measurement approaches are not closely aligned with the proposed cascade. For widespread adoption, there is a need for greater standardisation of indicator definitions and transparency in reporting, so governments can use these measures to improve investments in MNACHN and implement life-saving health policies and programs.

5.2 Introduction

Maternal, newborn, child and adolescent health and nutrition (MNCAHN) is a key priority for the global health and development agenda (WHO). Maternal, newborn and child deaths are mostly preventable as the interventions that prevent or treat the major causes of ill health are known. However, deaths in these populations remain unacceptably high and disproportionately occur in low- and middle-income countries (LMICs) (WHO, UNICEF et al. 2019). Improving both accessibility to and the quality of effective interventions is key to improving health outcomes for women and children (Kruk, Gage et al. 2018).

Efforts to improve MNCAHN globally have been supported by the tracking of global and national health goals, including the Sustainable Development Goals, that typically measure contact coverage, defined as the proportion of a population in need of a service or intervention that received the service (WHO , Boerma, Requejo et al. 2018, Moran, Moller et al. 2018, Moller, Patten et al. 2019). There is evidence that contact coverage indicators overestimate the health benefits of an intervention or service as they do not adequately capture the quality of care (QoC) delivered (Requejo, Newby et al. 2013, Grove, Claeson et al. 2015, Marchant, Bryce et al. 2016, Amouzou, Leslie et al. 2019). Effective coverage measures that move beyond contact coverage by also accounting for QoC, are now recommended as best practice (Murray and Evans 2003, Ng, Fullman et al. 2014, Kruk, Gage et al. 2018). Effective coverage indicators estimate the proportion of a population in need of a service that received the service with sufficient quality to achieve a positive health outcome. In this way they aim to estimate better the true benefit of an intervention or service (Shengelia, Tandon et al. 2005, Ng, Fullman et al. 2014, Jannati, Sadeghi et al. 2018, Kruk, Gage et al. 2018, Amouzou, Leslie et al. 2019).

Measurement of QoC is challenging as multiple dimensions need to be examined. QoC can be measured in terms of inputs (e.g. adequacy of facilities, equipment and resources, trained and adequate number of health care professionals), processes (e.g. appropriate use of effective clinical and non-clinical interventions) and outcomes (e.g. avoidable mortality and morbidity, improved health and well-being) (Donabedian 1988). Increasingly there is a focus on a patient-centred approach, which also considers experience of care and the right to be treated with respect (Tunçalp, Were et al. 2015, WHO 2016, Kruk, Gage et al. 2018). Studies have used various indicators to measure QoC and several definitions for effective coverage have been proposed (Tanahashi 1978, WHO 2001, Murray and Evans 2003, Shengelia, Tandon et al. 2005, Ng, Fullman et al. 2014, WHO and The World Bank 2015, Amouzou, Leslie et al. 2019, GBD 2019 Universal Health Coverage Collaborators 2020).

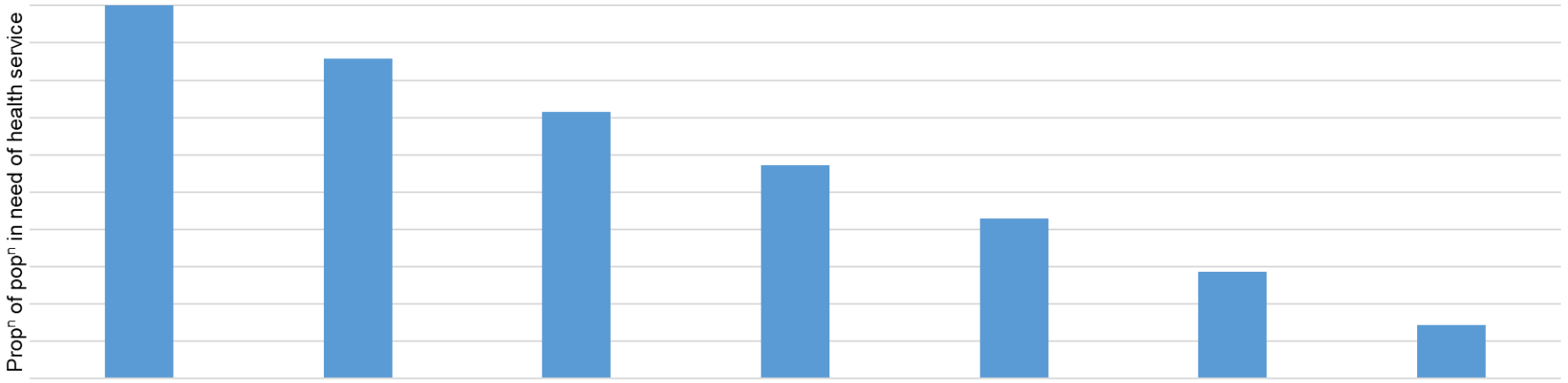
In 2019, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) convened a group of experts - the Effective Coverage Think Tank Group - to establish standardised definitions and measurement approaches of effective coverage for MNCAHN. This expert group considered findings from two previous reviews of effective coverage measures and applications (Jannati, Sadeghi et al. 2018, Amouzou, Leslie et al. 2019) and recommended the adoption of a 'health-service coverage cascade', presented in Figure 5-1 (Marsh, Muzigaba et al. 2020). This cascade outlines six steps, presented sequentially for analytical purposes, with each step accounting for different dimensions of QoC: 1) the population in need (target population) who contact a health service; 2) that has the inputs available to deliver the service; 3) who receive the health service; 4) according to quality standards (referred to in this paper as 'process quality'); 5) and adhere to prescribed medication(s) or health workers instructions; and (6) experience the expected health outcome.

Effective coverage is, ideally, estimated as the final step of the cascade (outcome-adjusted coverage) and incorporates all previous steps into one summary measure. However, the feasibility of measuring outcome-adjusted coverage depends upon the type of intervention and is most suitable where the health impact can be directly linked to an intervention (e.g. treatment of children with severe malnutrition with specially formulated foods). Conversely, some services, such as childbirth care, integrate multiple interventions into a single health contact making outcome-adjusted coverage challenging to estimate directly. Here process quality-adjusted coverage may be a more suitable proxy measurement of effective coverage.

Discussions regarding the use of this effective coverage cascade for tracking MNCAHN services have been largely conceptual. Challenges remain in operationalising the cascade (including defining the content and data source of each cascade step), providing guidance for linking data from multiple sources to calculate each step, and ensuring that the cascade is responsive to the needs of different types of decision makers, including programme managers and policy makers (Marsh, Muzigaba et al. 2020). If effective coverage measures are to have wide-scale uptake, then there is a need for more guidance on how they can be constructed and used to identify health service strengths and weaknesses.

We report results from a rapid systematic review and evidence synthesis examining how effective coverage measures of life-saving interventions from childbirth to children up to nine years of age have been defined in the literature. This review specifically sought to map the individual items and data sources used to construct effective coverage measures against the steps of the coverage cascade, to identify which steps of the cascade contact coverage have been adjusted for, and to reflect on the implications for the widespread adoption of the proposed cascade.

Figure 5-1 Health service coverage cascade for measuring effective coverage



Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	(Process) quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
popⁿ with a specific health need	propⁿ of the popⁿ in need who come into contact with the (relevant) health service	propⁿ of the popⁿ in need who come into contact with a service ready to provide care. Readiness requires that all inputs necessary to provide the service are available in sufficient quantity and quality and are usable at the time of the visit.	propⁿ of the popⁿ in need who come into contact with a service that is ready and receives the service.	propⁿ of the popⁿ in need who come into contact with a service that is ready and receives the service according to quality-of-care standards. Quality of care extends beyond adherence to guidelines to also consider whether the service was provided respectfully.	propⁿ of the popⁿ in need who receives a service according to quality-of-care standards and that adheres to provider instructions.	propⁿ of the popⁿ in need who receives a service according to quality-of-care standards, adheres to provider instructions, and has the expected health outcome (either a return to good health or the absence of health loss).

FIGURE NOTE: Adapted from Marsh et al. 2020 (Marsh, Muzigaba et al. 2020)

5.3 Methods

We applied a rapid review approach, following standardised methods and reported in accordance with PRISMA guidelines (Grant and Booth 2009, Tricco, Langlois et al. 2017, Cumpston, Li et al. 2019, Page, McKenzie et al. 2021).

5.3.1 Information sources and search strategy

The two earlier reviews of effective coverage that informed the development of the coverage cascade provided the basis of our search strategy (Jannati, Sadeghi et al. 2018, Amouzou, Leslie et al. 2019). These two reviews examined the types of interventions assessed using effective coverage and the size of the gap between contact coverage and quality-adjusted coverage measures. Our review examines the content of those measures in detail. We searched the reference lists of the two earlier reviews to identify potentially relevant studies. To identify articles published since the two earlier reviews, seven databases were searched: Embase (using OVID); MEDLINE (using OVID); ProQuest, ScienceDirect, Scopus, SpringerLink, and Web of Science covering the period from May 1, 2017 to July 8, 2021. We devised the search syntax by updating the search strategy from the two earlier reviews related to two concepts: 1) effective coverage; AND 2) the target population and/or intervention. Searches were restricted to studies in countries categorised as LMICs by the World Bank at the time of the search and all search terms used were in English (The World Bank 2020). The complete list of search terms used for the EMBASE and MEDLINE searches are presented in Table S1 in appendix 2.

Additional studies were identified through citation searches, conducted using the 'cited by' function in Google Scholar to identify subsequent studies that had cited the reviews. To ensure no key publications were missing members of the Child Health Accountability Tracking (CHAT) Advisory Group and study authors, including representatives from Mother and Newborn Information for Tracking Outcomes and Results (MoNITOR) Advisory Group , were consulted.

5.3.2 Eligibility criteria

Studies conducted in any LMIC that aimed to measure a population-level adjusted contact coverage estimate of life-saving interventions from childbirth to children up to nine years of age was eligible for inclusion. The age range was selected to capture interventions of interest to CHAT, which is tasked with standardising global monitoring indicators measuring the health of children aged 1 month to 9 years. Due to interest among the study authors' and the links between maternal, newborn and child health, this age range was expanded to include interventions around childbirth and the immediate newborn period. Eligible studies needed to combine at least three components of effective coverage: population in need,

service use and at least one other dimension from the coverage cascade. No restrictions were placed on the definition of QoC applied by the author or the data source(s) used as long as population level measures were derived. The inclusion and exclusion criteria are summarised in Table 5-1.

Table 5-1 Inclusion and exclusion criteria

	Inclusion	**Exclusion**
Population/setting	• Studies conducted in any low- or middle-income setting. • Studies that defined the target population in need of a health service or intervention. • Studies conducted among women during childbirth, newborns and children up to 9 years of age. • Studies conducted in health facilities, communities or home.	• Studies conducted in high income settings. • Studies that did not define and quantify the target population in need.
Interventions	Studies that examined essential lifesaving interventions provided during childbirth through childhood up to 9 years of age (The Partnership for Maternal Health, Newborn and Child Health et al. 2011): • Childbirth and postnatal care e.g. social support, prevention of postpartum haemorrhage, induction of labour, management of postpartum haemorrhage, HIV therapy. • Immediate essential newborn care e.g. thermal protection, immediate drying and additional stimulation, neonatal resuscitation, clean cord care. • Small and sick babies e.g. kangaroo mother care, extra support for feeding small and preterm baby, prophylactic and therapeutic use of surfactant, management of jaundice. • Infancy and childhood e.g. exclusive breastfeeding for first 6 months, complementary feeding, prevention and management of malaria, care for HIV, management of acute malnutrition, management of pneumonia, management of diarrhoea, management of meningitis, routine immunization, Vitamin A supplementation from 6 months.	
Outcome measures	• Any study that presented the methods used to measure a population-level adjusted contact coverage measure. • Studies needed to define the following three components: ○ Need: population in need of the intervention or service.	• Studies that do not provide sufficient detail on the items used to construct the effective coverage measure in the paper, appendices, or other supporting information. • Studies that do not measure all three components of effective coverage (need, use, quality).

	○ Use: population that comes into contact with a service or received a specific intervention; AND. ○ Quality of care: at least one dimension of QoC as defined by the study authors, can include inputs or process measures of quality as well as health outcomes.	
Comparisons	n/a	
Study design	• Studies using any study design or data source to estimate effective coverage. • Abstracts and conference presentations, if enough data presented to determine how effective coverage measure constructed.	• Commentaries and editorials • Reviews • Technical reports
Language	• Studies published in English	• Studies not published in English

5.3.3 Selection process

Retrieved title and abstract records were loaded into the reference manager programme Endnote X7 and duplicate references were removed (The Endnote team 2013). Two reviewers (JE and PG) double screened 15% of the records to ensure consistency in selection between the reviewers (Cronbach's alpha = 0.86). The two reviewers independently screened the remaining titles and abstracts (either JE or PG).

Full-texts of potentially relevant studies identified from the title and abstract screening were obtained and screened by both reviewers (JE and PG), with any uncertainties discussed between the two reviewers. Where we were unable to access the full-text, the study authors were contacted via email. The reason for excluding studies based on full-text review was recorded.

5.3.4 Data collection process and risk of bias assessment

Study information was extracted into a standardised table to capture data on how effective coverage measures were constructed and defined, which individual items were included, the methods for construction of any composite scores and the data sources used.

Given the review's focus, data on the study results was not extracted and a formal quality assessment or risk of bias assessment was not undertaken. Information from included studies was extracted by one reviewer and checked by a second reviewer (JE or PG).

5.3.5 Synthesis

Studies were grouped by population group (women, newborns, children under five and children aged five to nine) and intervention or health service type. For each group of studies, we extracted the individual items used to construct the effective coverage measure and

mapped these against the seven steps of the effective coverage cascade presented in Figure 5-1. To ensure consistency in our approach to this mapping, we classified items based on definitions outlined in Box 5-1. Evidence is summarised in a narrative synthesis with data presented in tables.

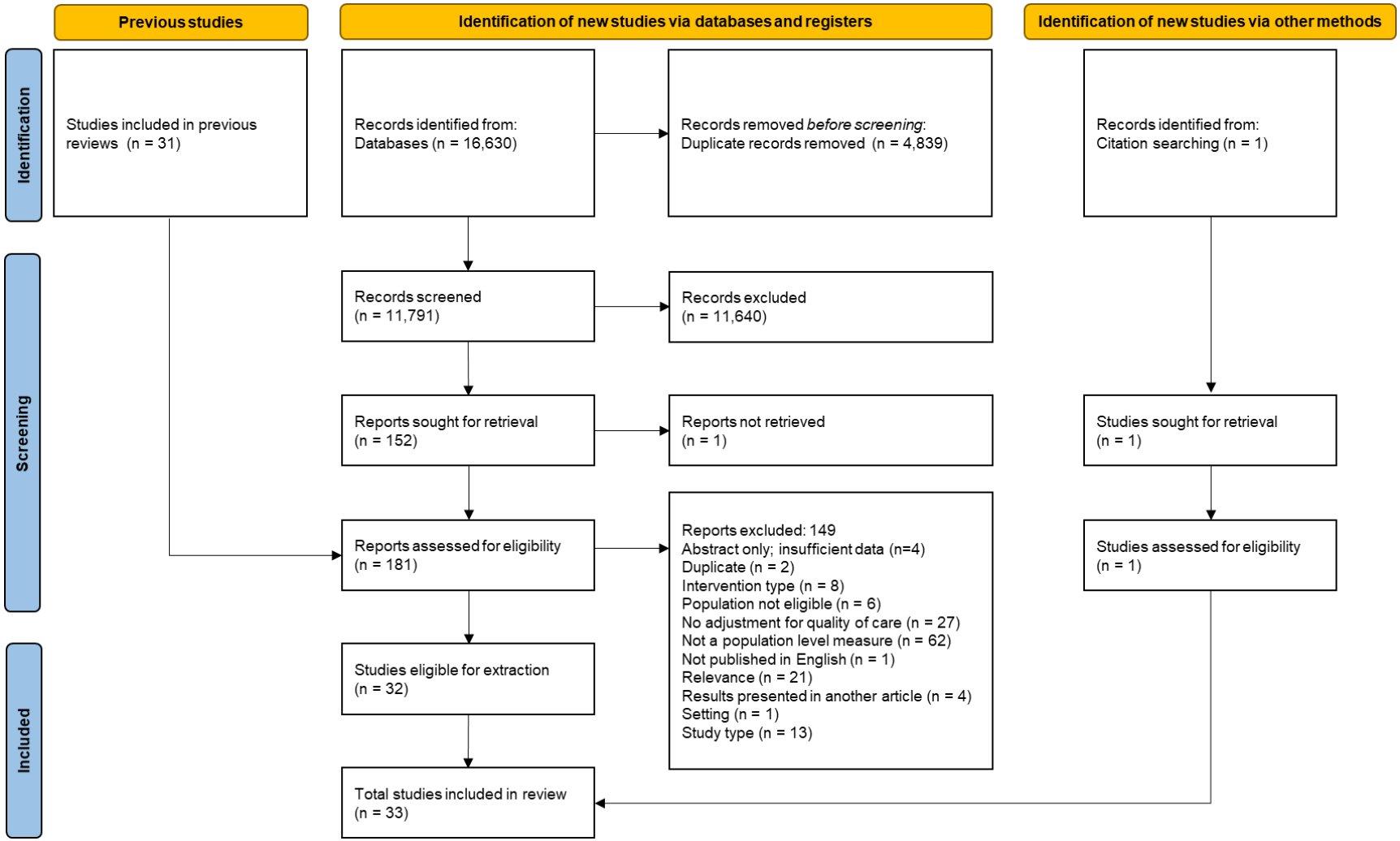
Box 5-1 Definitions of the seven steps of the coverage cascade used to synthesis evidence across included studies

- **Target population:** individuals in need of a health service or intervention based on belonging to either a specific group e.g. pregnant women or the presence of a specific disease/condition e.g. child with fever.
- **Service contact:** individuals who sought or received needed care.
- **Inputs:** health service readiness to provide care, includes facility infrastructure, availability and competence of staff, availability of supplies and commodities.
- **Intervention:** receipt of clinical and non-clinical interventions administered to provide a direct health benefit.
- **Process (quality):** receipt of interventions and behaviours that enhance interactions, including effective communication, respectful care and emotional support.
- **User-adherence:** service user adheres to prescribed medications or provider instructions.
- **Outcome:** health outcome.

5.4 Results

Database searches identified 16,630 records (see Figure 5-2). After removal of duplicates, we screened 11,791 records of which 151 were considered for full-text review. In addition, 32 papers were identified through other methods for full-text review. Of those papers assessed in the full-text review 33 studies were identified as eligible for inclusion. Table S2 in appendix 2 lists reference details of excluded studies and reasons for exclusion based on the full-text review.

Figure 5-2 PRISMA diagram



5.4.1 Summary of included studies

A complete description of included studies is presented in Table S3 in appendix 2. Table 5-2 presents an overview of the number of studies reporting effective coverage measures by the type of service or intervention and population group. The most frequently examined interventions were facility-based childbirth and immediate newborn care, followed by sick child care. The majority of studies were conducted among women and newborns; we identified no studies that included children aged five to nine years.

Table 5-2 Number of studies that constructed an effective coverage measure for each health service or intervention by population group

Women and newborns	Children under 5	Children aged 5 to 9
Facility based childbirth and/or immediate newborn care, n=17 Postnatal care for women and/or newborn, n=8 Care of sick newborns, n=1 Exclusive breastfeeding, n=1	Sick child care, n=10 Complementary feeding, n=5 Growth monitoring, n=1 Insecticide treated bednets (ITN), n=1 Vaccines, n=4	No studies identified

The majority of studies were conducted in a single country (27 out of 33), see Figure 5-3; six studies were conducted across multiple countries, four of which included countries across different regions of the world (Marchant, Tilley-Gyado et al. 2015, Mokdad, Gagnier et al. 2015, Carvajal-Aguirre, Amouzou et al. 2017, Leslie, Malata et al. 2017, Kanyangarara, Chou et al. 2018, Wang, Mallick et al. 2019). Studies were most frequently conducted in countries in sub-Saharan Africa (27 out of 33); Kenya and Tanzania were the most frequently studied countries (6 out of 33), while 17 countries were included in only one study. The majority of studies used primary data collected at a sub-national level, see Figure 5-4. For the 12 studies conducted at the national level, one conducted in Mexico used the nationally representative Mexican National Health and Nutrition Survey (ENSANUT) and routine health information from the Mexican Institute of Social Security (IMSS) (Leslie, Doubova et al. 2019). The rest used nationally representative household surveys (Demographic and Health surveys [DHS] and/or Multiple Indicator Cluster Survey [MICS]) and health facility assessments (Service Provision Assessment [SPA] and/or Service Availability and Readiness Assessment [SARA]). Thirteen studies used a single source of data (DHS or primary household surveys) and one study of sick newborns estimated the population in need by applying the rate of newborns needing inpatient care to an estimate of the number of live births in the study area (Murphy, Gathara et al. 2018). The remaining 18 studies linked two or more sources of data, most frequently household and health facility data. Six studies also included direct observations of clinical care either from SPA (Leslie,

Malata et al. 2017, Nguhiu, Barasa et al. 2017, Sharma, Leslie et al. 2017, Joseph, Piwoz et al. 2020) or as part of a primary health facility assessment (Koulidiati, Nesbitt et al. 2018, Munos, Maiga et al. 2018).

Figure 5-3 Number of studies conducted by country and region

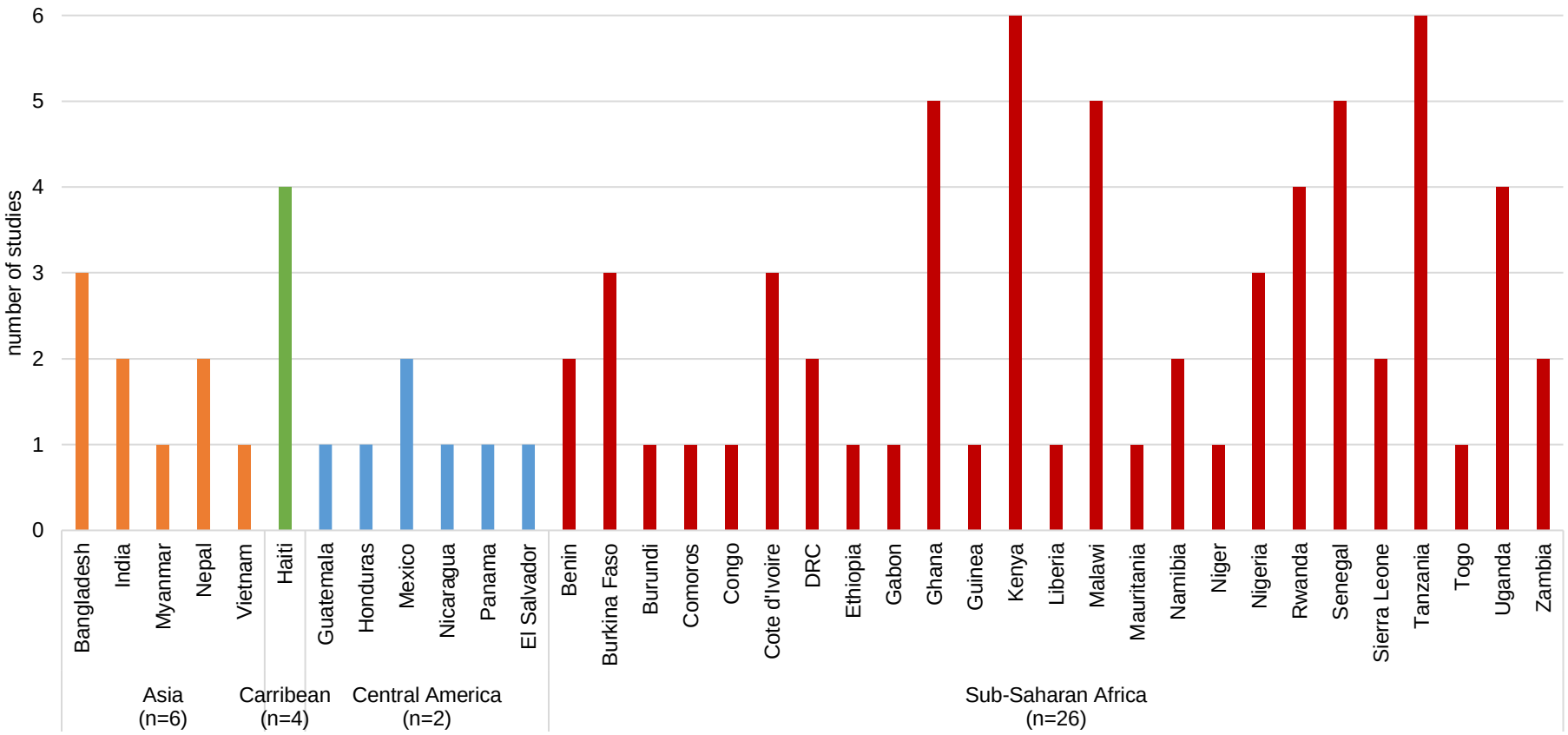


FIGURE NOTE: n indicates the total number of studies that included countries from the region. Six studies included multiple countries in the analysis; four included countries across multiple regions (Marchant, Tilley-Gyado et al. 2015, Leslie, Malata et al. 2017, Kanyangarara, Chou et al. 2018, Wang, Mallick et al. 2019) and two included countries from a single region (Mokdad, Gagnier et al. 2015, Carvajal-Aguirre, Amouzou et al. 2017)

Figure 5-4 Number of studies by data source used to construct effective coverage measure and level of data collection

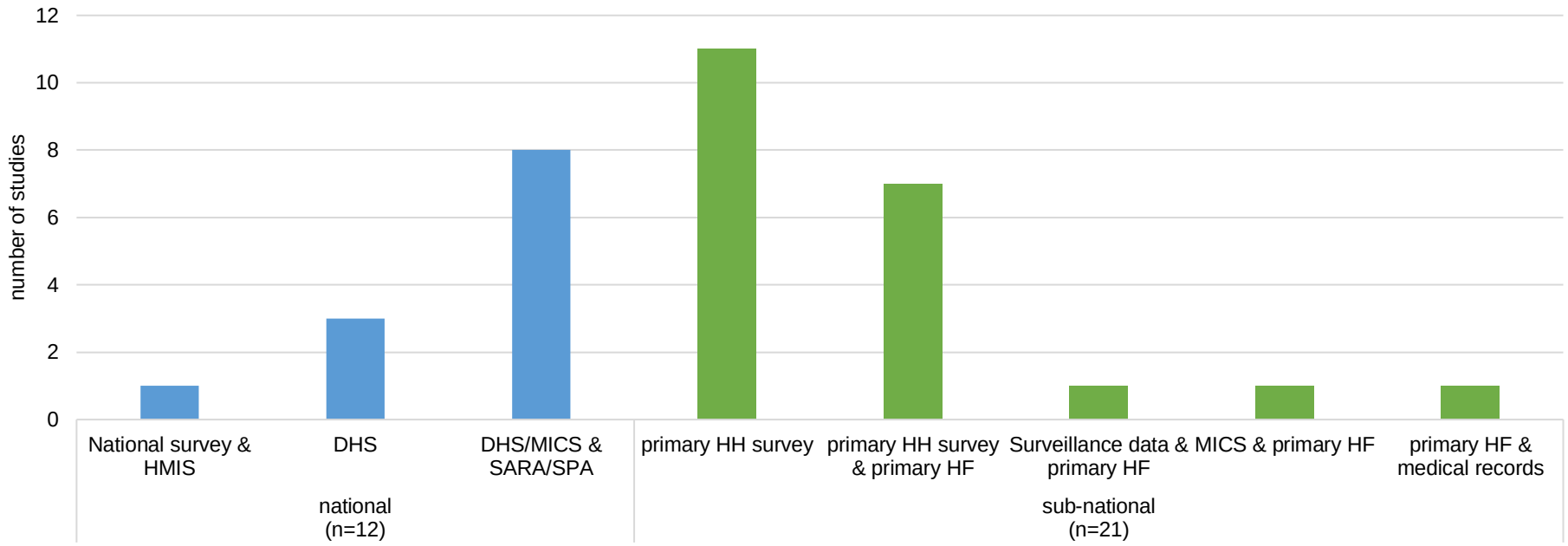


FIGURE NOTE: Primary HH survey and primary HF indicate primary data collection undertaken by the study authors. Two studies conducted observations of care as part of the HF survey (Koulidiati, Nesbitt et al. 2018, Munos, Maiga et al. 2018) and four studies included observations collected as part of SPA (Leslie, Malata et al. 2017, Nguhiu, Barasa et al. 2017, Sharma, Leslie et al. 2017, Joseph, Piwoz et al. 2020). One study examining childbirth, immediate newborn care and sick child care, used the Mexican National Health and Nutrition Survey (ENSANUT) and routine data: the Mexican Institute of Social Security (IMSS) performance indicators from health management information systems (Leslie, Doubova et al. 2019). Surveillance data refers to demographic surveillance data collected as part of the Newhints trial (Nesbitt, Lohela et al. 2013). One study of sick newborns did not include a household survey, instead authors estimated the population in need by applying the rate of live births requiring inpatient services to the total number of live births extrapolated from the DHS (Murphy, Gathara et al. 2018).

DHS=Demographic Health Survey, ENSANUT=Mexican National Health and Nutrition Survey, HF= health facility survey, HH=household survey, IMSS= Mexican Institute of Social Security performance indicators from health management information systems, MICS=Multiple Indicator Cluster Surveys, SARA=Service Availability and Readiness Assessment, SPA=Service Provision Assessment

5.4.2 Definition and construction of effective coverage measures

Overall, 64 measures that met the eligibility criteria were reported across the 33 studies; 36 measures of interventions among women and newborns (Table 5-3), 29 measures among children under five (Table 5- 4), and 0 measures for children ages five to nine. Seventeen studies explicitly defined the measures as effective coverage, three studies referred to measures as effective coverage but reported them according to the adjustments made: input-adjusted coverage (Carter, Ndhlovu et al. 2018, Nguyen, Khương et al. 2021) and structure-adjusted coverage and process-adjusted coverage (Munos, Maiga et al. 2018). The remaining studies did not use the term effective coverage, instead measures were defined as: adequate contact with high quality care (Okawa, Gyapong et al. 2019), content coverage (Carvajal-Aguirre, Amouzou et al. 2017), coverage of obstetric services (Kanyangarara, Chou et al. 2018), facility readiness (Kemp, Sorensen et al. 2018), high quality contacts (Marchant, Tilley-Gyado et al. 2015), missed opportunities (Mokdad, Gagnier et al. 2015), population access to quality care (Sharma, Leslie et al. 2017), quality coverage (Sheff, Bawah et al. 2020), quality-adjusted contact (Okawa, Win et al. 2019), quality-adjusted coverage (Joseph, Piwoz et al. 2020) and treatment pathway (Smith, Bruce et al. 2010, Millar, McCutcheon et al. 2014).

Tables 5-3 and 5-4 present a summary of the items and data sources used to construct each measure, mapped against the steps of the coverage cascade. Within each table, measures are grouped by intervention or health service. The comprehensive mapping, including full details of the items, is presented in Tables S4 to S12 in appendix 2. The terminology used by study authors often did not align with the terminology used in the coverage cascade, examples of how we operationalised the cascade given these inconsistencies are presented in Box 5-2. Findings highlight that no standardised effective coverage measure has been used to date in the literature for MNCAHN interventions or services. In the rest of this section, we highlight some of the key differences in how studies have defined effective coverage measures.

Box 5-2 Operationalising the coverage cascade

The dimensions of QoC examined and the terminology used to describe the dimensions of QoC varied between studies (see Table S3 in appendix 2) and did not typically align with the steps of the proposed coverage cascade.

The input step was the most straightforward to operationalise, although different overarching terms were used across studies including: input indicators (Koulidiati, Nesbitt et al. 2018), facility/service readiness (Mokdad, Gagnier et al. 2015, Kanyangarara, Chou et al. 2018, Kemp, Sorensen et al. 2018, Koulidiati, Nesbitt et al. 2018, Willey, Waiswa et al. 2018, Wang, Mallick et al. 2019) and structural quality/indicators (Nguhiu, Barasa et al. 2017, Carter, Ndhlovu et al. 2018, Koulidiati, Nesbitt et al. 2018, Munos, Maiga et al. 2018, Murphy, Gathara et al. 2018).

No studies distinguished between intervention- and process-quality indicators as proposed in the coverage cascade. Instead, items related to these two steps were typically captured under a single quality domain. Studies used a range of terms to describe this aspect of QoC including provision of care (Larson, Vail et al. 2017), competent care (Okawa, Win et al. 2019, Hategeka, Arsenault et al. 2020), systems competence (Hategeka, Arsenault et al. 2020), technical quality (Leslie, Malata et al. 2017), process quality/indicators (Marchant, Tilley-Gyado et al. 2015, Koulidiati, Nesbitt et al. 2018, Munos, Maiga et al. 2018, Murphy, Gathara et al. 2018), receipt of interventions (Baker, Peterson et al. 2015, Carvajal-Aguirre, Amouzou et al. 2017, Joseph, Piwoz et al. 2020), signal functions (Nesbitt, Lohela et al. 2013) and clinical care processes (Sharma, Leslie et al. 2017). In mapping studies against the cascade, we classified the individual items measured under the intervention or process-quality step based on definitions presented in Box 5-1.

Table 5-3 Mapping effective coverage measures for women and newborns against the steps of the coverage cascade: by health service or intervention type and the data source and the number of items to measure each step.

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
CHILDBIRTH &/OR IMMEDIATE NEWBORN CARE (Table S4 in Appendix 2)									
Nesbitt et al. 2013 (Nesbitt, Lohela et al. 2013)	Effective coverage	Intrapartum & immediate newborn care	Surveillance	Surveillance	HF, n=20	HF (HCW), n=24	HF (HCW), n=3		
Larson et al. 2017 (Larson, Vail et al. 2017)	Effective coverage	Obstetric care	HH	HH	HF, n=37	HF records, n=4	HF records, n=2		
Baker et al. 2015 (Baker, Peterson et al. 2015)	Effective coverage	Active management of third stage of labour	HH	HH	HF, n=2	HF (HCW), n=1			
	Effective coverage	Use of partograph to monitor labour	HH	HH	HF, n=1		HF (HCW), n=1		
Munos et al. 2018 (Munos, Maiga et al. 2018)	Process-adjusted coverage	Labour & delivery	MICS	MICS	HF, n=9		HF (HCW), n=10		
Kanyangarara et al. 2018 (Kanyangarara, Chou et al. 2018)	Coverage of obstetric services: readiness	Obstetric service	DHS/MICS	DHS/MICS, n=1	SPA/SARA, n=23				
	Coverage of obstetric services: service availability	Obstetric service	DHS/MICS	DHS/MICS	SPA/SARA, n=9				
Kemp et al. 2018 (Kemp, Sorensen et al. 2018)	Facility readiness	Facility delivery	DHS	DHS	SARA, n=70				
Wang et al. 2019 (Wang, Mallick et al. 2019)	Effective coverage	Facility delivery	DHS	DHS	SPA, n=53				
Munos et al. 2018 (Munos,	Structure-adjusted coverage	Labour & delivery	MICS	MICS	HF, n=33				

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
Maiga et al. 2018)									
Sharma et al. 2017 (Sharma, Leslie et al. 2017)	Population access to quality infrastructure	Delivery care	DHS	DHS	SPA, n=20				
Willey et al. 2018 (Willey, Waiswa et al. 2018)	Effective coverage	Basic emergency obstetric care	HH	HH	HF, n=18				
Nguhiu et al. 2017 (Nguhiu, Barasa et al. 2017)	Effective coverage	Skilled delivery & perinatal care	DHS	DHS	SPA, n=9				
Munos et al. 2018 (Munos, Maiga et al. 2018)	Structure-adjusted coverage	Immediate newborn care	MICS	MICS	HF, n=9				
Nguyen et al. 2021 (Nguyen, Khương et al. 2021)	Input-adjusted coverage	Birth care	DHS	DHS	SPA, n=5				
Sharma et al. 2017 (Sharma, Leslie et al. 2017)	Population access to quality care	Delivery care	DHS	DHS		SPA, n=12	SPA, n=6		
Munos et al. 2018 (Munos, Maiga et al. 2018)	Process-adjusted coverage	Immediate newborn care	MICS	MICS		HF (HCW), n=17	HF (HCW), n=2		
Okawa et al. 2019a (Okawa, Win et al. 2019)	Quality-adjusted contact	Peripartum care	HH	HH		HH, n=6	HH, n=1		
Joseph et al. 2020 (Joseph, Piwoz et al. 2020)	Quality-adjusted coverage	Post-delivery care	MICS	MICS		SPA, n=2	SPA, n=1		
Okawa et al. 2019b (Okawa, Gyapong et al. 2019)	Adequate contacts with high quality care	Peripartum care	HH	HH		HH, n=3			
Marchant et al. 2015	High quality contact	Prevention of haemorrhage	HH	HH		HF (HCW), n=2			

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
(Marchant, Tilley-Gyado et al. 2015)									
Shibanuma et al. 2018 (Shibanuma, Yeji et al. 2018)	Continuum of Care achievement	Facility delivery	HH	HH		HH, n=2			
Leslie et al. 2019 (Leslie, Doubova et al. 2019)	Effective coverage	Delivery care	ENSANUT	HMIS					HMIS, n=1
		Immediate newborn care	ENSANUT	HMIS					HMIS, n=1
CARE OF SICK NEWBORNS (Table S5 in Appendix 2)									
Murphy et al. 2018 (Murphy, Gathara et al. 2018)	Effective coverage	Inpatient neonatal care	Estimate*	Medical records	HF, n=127	Medical records, n=3	Medical records, n=28		
EXCLUSIVE BREASTFEEDING (Table S6 in Appendix 2)									
Nguhiu et al. 2017 (Nguhiu, Barasa et al. 2017)	Effective coverage	Exclusive Breastfeeding	DHS	DHS				DHS, n=1	
POSTNATAL CARE (Table S7 in Appendix 2)									
Baker et al. 2015 (Baker, Peterson et al. 2015)	Effective coverage	PPC for women within 48hrs of delivery	HH	HH	HF, n=1		HH, n=1		
Munos et al. 2018 (Munos, Maiga et al. 2018)	Structure-adjusted coverage	Post-discharge PNC for women and baby within 2 days of birth	HH	HH	HF, n=24				
Okawa et al. 2019a (Okawa, Win et al. 2019)	Quality-adjusted contact	PNC for women and newborn	HH	HH		HH, n=6	HH, n=11		
Okawa et al. 2019b (Okawa, Gyapong et al. 2019)	Adequate contacts with high quality care	PNC for women and newborn	HH	HH		HH, n=4	HH, n=10		

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
Carvajal Aguirre et al 2017 (Carvajal-Aguirre, Amouzou et al. 2017)	Content coverage	PNC for women and baby	DHS	DHS		DHS, n=3	DHS, n=2	DHS, n=2	
Shibanuma et al. 2018 (Shibanuma, Yeji et al. 2018)	Continuum of Care achievement	PNC for women and child within 48hrs, 2 & 6 wks post-delivery	HH	HH		HH, n=1	HH, n=2		
Munos et al. 2018 (Munos, Maiga et al. 2018)	Process-adjusted coverage	PNC for women and baby within 2 days of birth	HH	HH		O, n=3	O, n=8		
Marchant et al. 2015 (Marchant, Tilley-Gyado et al. 2015)	High quality contact	PPC for women within 48hrs of birth	HH	HH			HH, n=3		
		PNC for newborn within 48 hrs of birth	HH	HH		HH, n=1	HH, n=2		
Hategeka et al. 2020 (Hategeka, Arsenault et al. 2020)	Effective coverage	PPC for women before discharge	DHS	DHS			DHS, n=2		

TABLE NOTE: Green indicates items measured that map to steps of Marshes' coverage cascade while pink indicates no items measured. Grey box indicates steps of the cascade that Marsh considers are not amenable to measurement for a particular service.

* Murphy et al. estimated the target population by extrapolating rate of newborns requiring inpatient services to the total number of live births in the study population (Murphy, Gathara et al. 2018).

DHS=Demographic Health Survey, ENSANUT=Mexican National Health and Nutrition Survey, HCW= healthcare worker interview (conducted as part of a health facility assessment), HF= health facility assessment, HH=household survey, HMIS= Health Management Information System, MICS=Multiple Indicator Cluster Surveys, n=number of items used to measure indicator, O=observations, PPC=post-partum care, PNC=post-natal care, SPA=Service Provision Assessment.

Table 5-4 Mapping effective coverage measures for children under five against the steps of the coverage cascade: by health service or intervention type and the data source and the number of items to measure each step.

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
SICK CHILD CARE (Table S8 in Appendix 2)									
Koulidiati et al. 2018 (Koulidiati, Nesbitt et al. 2018)	Effective coverage	Treatment of illness	HH	HH	HF, n=16		O, n=8		
Nguhiu et al. 2017 (Nguhiu, Barasa et al. 2017)	Effective coverage	Quality primary care for children: treatment of ARI and/or fever	DHS	DHS	SPA, n=2		SPA, n=5		
Munos et al. 2018 (Munos, Maiga et al. 2018)	Structure-adjusted coverage	Care seeking fever, cough, or diarrhoea	MICS	MICS	HF, n=25				
Carter et al. 2018 (Carter, Ndhlovu et al. 2018)	Input based effective coverage	Treatment of diarrhoea, fever, ARI or a combination	HH	HH	HF, n=20				
Nguyen et al. 2021 (Nguyen, Khương et al. 2021)	Input-adjusted coverage	Treatment of diarrhoea or ARI	DHS	DHS	SPA, n=9				
Leslie et al. 2017 (Leslie, Malata et al. 2017)	Effective coverage	Treatment for diarrhoea, fever or ARI	DHS/MICS	DHS/MICS		SPA, n=2	SPA, n=20		
Smith et al. 2010 (Smith, Bruce et al. 2010)	Treatment pathway	Treatment for malaria	HH	HH		HH, n=2	HH, n=1		
Millar et al. 2014 (Millar, McCutcheon et al. 2014)	Treatment pathway	Treatment for malaria	HH	HH		HH, n=2	HH, n=1		
Hategeka et al. 2020 (Hategeka, Arsenault et al. 2020)	Effective coverage	Treatment for diarrhoea	DHS	DHS		DHS, n=1			
		Treatment for pneumonia	DHS	DHS		DHS, n=1			
		Treatment for malaria	DHS	DHS		DHS, n=1			
Munos et al. 2018 (Munos, Maiga et al. 2018)	Process-adjusted coverage	Care seeking fever, cough, or diarrhoea	MICS	MICS			O, n=6		

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
Leslie et al. 2019 (Leslie, Doubova et al. 2019)	Effective coverage	Treatment for ARI	ENSANUT	HMIS					HMIS, n=1
		Treatment for diarrhoea	ENSANUT	HMIS					HMIS, n=1
COMPLEMENTARY FEEDING (Table S9 in Appendix 2)									
Aaron et al. 2016 (Aaron, Strutt et al. 2016)	Effective coverage	Complementary feeding supplement	HH	HH		HH, n=1		HH, n=1	
Leyvraz et al. 2016a (Leyvraz, Rohner et al. 2016)	Effective coverage	Fortified complementary food	HH	HH		HH, n=1		HH, n=2	
Leyvraz et al. 2016b (Leyvraz, Wirth et al. 2016)	Effective coverage	Fortified complementary food	HH	HH		HH, n=1		HH, n=2	
Leyvraz et al. 2018 (Leyvraz, David-Kigaru et al. 2018)	Effective coverage	Micronutrient powder	HH	HH		HH, n=1		HH, n=2	
Nguyen et al. 2016 (Nguyen, Poonawala et al. 2016)	Effective coverage	Micronutrient powder	HH	HH		HH, n=1		HH, n=2	
GROWTH MONITORING (Table S10 in Appendix 2)									
Nguyen et al. 2021 (Nguyen, Khương et al. 2021)	Input-adjusted coverage	Growth Monitoring	DHS	DHS	SPA, n=6				
ITN (Table S11 in Appendix 2)									
Nguhiu et al. 2017 (Nguhiu, Barasa et al. 2017)	Effective coverage	Use of ITN	DHS	DHS		DHS, n=1			
VACCINES (Table S12 in Appendix 2)									
Nguhiu et al. 2017 (Nguhiu, Barasa et al. 2017)	Effective coverage	Quality primary care for children: complete set of basic vaccines	DHS	DHS	SPA, n=2		SPA, n=5		
Mokdad et al. 2015 (Mokdad, Gagnier et al. 2015)	Missed opportunities	MMR vaccine: facilities with MMR in stock	HH	VC or HH	HF, n=1		VC or HH, n=1		
		MMR vaccine: facilities with	HH	VC or HH	HF, n=1		VC or HH, n=1		

Reference	Author reported measure	Health service or intervention	Target population	Service contact coverage	Input-adjusted coverage	Intervention coverage	Process quality-adjusted coverage	User-adherence adjusted coverage	Outcome-adjusted coverage
		MMR stock-out in last 3 months							
		MMR vaccine: facilities with ORS in stock	HH	VC or HH	HF, n=1		VC or HH, n=1		
Mmanga et al. 2021 (Mmanga, Mwenyenkulu et al. 2021)	Effective immunisation coverage	Complete set of basic vaccines	DHS	DHS		DHS, n=2	DHS, n=1		
Sheff et al. 2020 (Sheff, Bawah et al. 2020)	Quality coverage	Complete set of basic vaccines	HH	VC		VC, n=1	VC, n=1		
Mokdad et al. 2015 (Mokdad, Gagnier et al. 2015)	Missed opportunities	Timely MMR vaccine	HH	VC or HH			VC or HH, n=1		

TABLE NOTE: Green indicates items measured that map to steps of Marshes' coverage cascade while pink indicates no items measured. Grey box indicates steps of the cascade that Marsh considers are not amenable to measurement for a particular service.

DTP= diphtheria, pertussis, and tetanus, DHS=Demographic Health Survey, ENSANUT=Mexican National Health and Nutrition Survey, HCW= healthcare worker interview (conducted as part of a health facility assessment), HF= health facility assessment, HH=household survey, HMIS= Health Management Information System, ITN=insecticide treated bednet, MICS=Multiple Indicator Cluster Surveys, MMR=measles, mumps and rubella, n=number of items used to measure indicator, O=observations, ORS= oral rehydration solution, SPA=Service Provision Assessment, VC=vaccination card

5.4.3 Variation in how services and interventions are defined

Where multiple interventions were being delivered within a single service such as childbirth, postnatal care and sick child care, studies either reported a combined measure or separate measures for each intervention delivered (see Tables 3 and 4). For example, four studies of sick child care reported a single measure for a package of interventions for the management of childhood illness, including diagnosis and treatment of malaria, treatment of diarrhoea with oral rehydration solution and treatment of respiratory infections (Leslie, Malata et al. 2017, Carter, Ndhlovu et al. 2018, Koulidiati, Nesbitt et al. 2018, Munos, Maiga et al. 2018, Nguyen, Khương et al. 2021). Conversely, two studies on sick child care presented a separate measure for each intervention examined (Leslie, Doubova et al. 2019, Hategeka, Arsenault et al. 2020).

5.4.4 Variation in the number and type of steps of the coverage cascade adjusted for

The cascade specifies five steps that contact (or crude) coverage should be adjusted for to estimate effective coverage: inputs, interventions, process-quality, user-adherence and outcomes (see Figure 5-1). Tables 5-3 and 5-4 present a summary of the mapping of the individual items measured in each study against the steps of the cascade. Details of the specific items measured are presented in Tables S4 to S12 in Appendix 2.

In mapping the items from the studies against the coverage cascade, we identified only three studies (two examining childbirth and newborn care, and one neonatal care) that measured items related to all recommended steps of the cascade (Nesbitt, Lohela et al. 2013, Larson, Vail et al. 2017, Murphy, Gathara et al. 2018). It can be seen in Table 5-3 and 5-4 that only one study, conducted in Mexico, that aimed to estimate effective coverage of delivery and newborn care and care for children under five with diarrhoea and respiratory illness using administrative data (IMSS), adjusted contact coverage for health outcomes (Leslie, Doubova et al. 2019).

Just under half of the measures adjusted contact coverage for items from only one of the five cascade steps (31 out of 64 measures); the maximum number of cascade steps captured in a single adjusted measure was three (4 out of 64 measures) (Nesbitt, Lohela et al. 2013, Carvajal-Aguirre, Amouzou et al. 2017, Larson, Vail et al. 2017, Murphy, Gathara et al. 2018). The steps of the coverage cascade most commonly adjusted for varied by intervention or health service. For childbirth and immediate newborn care, the most common adjustment was for items related to the input step (15 out of 24 measures). For postnatal care, most measures were adjusted for items related to the process quality step (9 out of 10 measures). All complementary feeding measures adjusted for items related to intervention and user-adherence steps (5 out of 5 measures). For sick child care the most common

adjustments were for items related to the intervention and process quality steps (6 out of 14 measures). All vaccine measures were adjusted for the process quality cascade step (7 out of 7 measures).

Inputs were measured using health facility data. Items classified under intervention and process quality steps were estimated using a range of data sources. Sick child care, postnatal care and complementary feeding primarily derived data from women/caregivers' recall in household surveys, while childbirth and immediate newborn care most frequently used healthcare workers' reports of their actions taken in health facility assessments. Direct observations of care were only used in eight measures across six studies: two childbirth and newborn care (Sharma, Leslie et al. 2017, Joseph, Piwoz et al. 2020), one postnatal care (Munos, Maiga et al. 2018), four sick child care (Leslie, Malata et al. 2017, Nguhiu, Barasa et al. 2017, Koulidiati, Nesbitt et al. 2018, Munos, Maiga et al. 2018) and one vaccine (Nguhiu, Barasa et al. 2017). Nguhiu et al. 2017 adjusted their measures of care seeking for acute respiratory infection and/or fever and routine vaccination for the same 'quality of primary care for children' measure (consisting of seven items across the input and process cascade steps) (Nguhiu, Barasa et al. 2017). The receipt and timing of vaccination were based on vaccination cards, with caregivers' recall used when vaccine cards were not available.

5.4.5 Variation in the definitions of individual steps of the cascade and approach to generating a composite score

Studies varied in their approach to constructing measures. While some selected tracer items, others defined more comprehensive, composite, measures. For example, the total number of items used to measure inputs ranged from one to 127 (Baker, Peterson et al. 2015, Mokdad, Gagnier et al. 2015, Murphy, Gathara et al. 2018). Mapping items against the coverage cascade demonstrated that there was little consistency in the items used within different interventions or health services. For example, inputs can be broadly classified into four areas: 1) facility infrastructure, 2) staff, training and guidelines, 3) availability of supplies, commodities and equipment, and 4) service availability. Nine of the 15 childbirth and immediate newborn care measures that included inputs measured items related to facility infrastructure (Nesbitt, Lohela et al. 2013, Larson, Vail et al. 2017, Nguhiu, Barasa et al. 2017, Sharma, Leslie et al. 2017, Kanyangarara, Chou et al. 2018, Kemp, Sorensen et al. 2018, Munos, Maiga et al. 2018, Willey, Waiswa et al. 2018, Wang, Mallick et al. 2019). In total 13 different items were examined, ranging from two to eight items in a single measure (Kemp, Sorensen et al. 2018, Willey, Waiswa et al. 2018); none of the 13 items were common to all measures. Further, individual items were defined in different ways primarily based on the data source (see Table S4 in Appendix 2).

Items used to assess process quality of care were skewed towards provision of care. Only two measures, which both examined childbirth and immediate newborn care, included items related to patient experience or respectful care (Nesbitt, Lohela et al. 2013, Sharma, Leslie et al. 2017).

The justification for how items were selected was not always well described. Only 23 studies reported the approach taken, which varied across service or intervention type. International recommendations were most frequently cited as guiding item selection in studies of childbirth and sick child care (Smith, Bruce et al. 2010, Millar, McCutcheon et al. 2014, Marchant, Tilley-Gyado et al. 2015, Nguyen, Poonawala et al. 2016, Leslie, Malata et al. 2017, Kanyangarara, Chou et al. 2018, Kemp, Sorensen et al. 2018, Munos, Maiga et al. 2018, Shibanuma, Yeji et al. 2018, Okawa, Win et al. 2019, Wang, Mallick et al. 2019, Hategeka, Arsenault et al. 2020, Nguyen, Khương et al. 2021), while national guidelines were reported to inform timing and completeness of vaccinations (Mokdad, Gagnier et al. 2015, Sheff, Bawah et al. 2020, Mmanga, Mwenyenkulu et al. 2021). Differences in national priorities account for some of the variation in the items selected, for example two studies, one in Kenya and the other in Ghana, included different packages of vaccines based on the respective national guidelines (Nguhiu, Barasa et al. 2017, Sheff, Bawah et al. 2020). Several studies reported that selection was based on previous literature (Nesbitt, Lohela et al. 2013, Nguyen, Poonawala et al. 2016, Sharma, Leslie et al. 2017, Kanyangarara, Chou et al. 2018, Koulidiati, Nesbitt et al. 2018, Shibanuma, Yeji et al. 2018, Willey, Waiswa et al. 2018, Okawa, Win et al. 2019, Wang, Mallick et al. 2019). Two studies reported that selection was in part informed in consultation with local clinicians and health administrators at the study site (Nesbitt, Lohela et al. 2013, Shibanuma, Yeji et al. 2018). Item selection was also reported to be influenced by data availability; one study examining change over time noted that item selection was restricted based on item availability across different datasets (Hategeka, Arsenault et al. 2020).

Studies have taken different approaches to generating a summary measure for QoC, including generating an average score, a binary score (based on all items being present or based on a threshold) and a categorical score. For example, taking studies of childbirth, Wang et al. (2019) calculated facility readiness to provide delivery care as the average number of items available standardised out of 100 (Wang, Mallick et al. 2019); Willey et al. (2018) classified facilities as ‘ready’ if they had all commodities measured available (Willey, Waiswa et al. 2018); Kanyangara et al. (2018) on the other hand classified facilities as ready to provide obstetric services if they had 20 or more of the 23 items measured available (Kanyangarara, Chou et al. 2018). Kanyangara et al. also assessed availability of obstetric services in health facilities and classified facilities into four levels of functionality based on

the number and type of signal functions performed: 1) comprehensive emergency obstetric care(CEmOC), 2) basic emergency obstetric care (BEmOC), 3) basic emergency obstetric care-2 (BEmOC-2), and 4) low/substandard.

Studies also took a different approach to generating an overall effective coverage measure. The majority presented a composite measure that adjusted contact coverage for all items measured (see Table S3 in Appendix 2) (Nesbitt, Lohela et al. 2013, Marchant, Tilley-Gyado et al. 2015, Carvajal-Aguirre, Amouzou et al. 2017, Leslie, Malata et al. 2017, Nguhiu, Barasa et al. 2017, Carter, Ndhlovu et al. 2018, Koulidiati, Nesbitt et al. 2018, Murphy, Gathara et al. 2018, Shibanuma, Yeji et al. 2018, Willey, Waiswa et al. 2018, Okawa, Gyapong et al. 2019, Okawa, Win et al. 2019, Wang, Mallick et al. 2019, Hategeka, Arsenault et al. 2020, Joseph, Piwoz et al. 2020, Nguyen, Khương et al. 2021). Three studies presented separate measures adjusted for different components of QoC (Sharma, Leslie et al. 2017, Kanyangarara, Chou et al. 2018, Munos, Maiga et al. 2018). For example, Munos et al. presented two adjusted measures for each intervention examined, one adjusting contact coverage for structural quality and the second adjusting for process quality. The remaining studies presented effective coverage as a cascade (Smith, Bruce et al. 2010, Millar, McCutcheon et al. 2014, Baker, Peterson et al. 2015, Mokdad, Gagnier et al. 2015, Aaron, Strutt et al. 2016, Leyvraz, Rohner et al. 2016, Leyvraz, Wirth et al. 2016, Nguyen, Poonawala et al. 2016, Larson, Vail et al. 2017, Leyvraz, David-Kigaru et al. 2018, Leslie, Doubova et al. 2019, Sheff, Bawah et al. 2020, Mmanga, Mwenyenkulu et al. 2021). While there was some consistency in approach between interventions, notably studies examining complementary feeding and malaria, there was no standard approach across studies.

5.5 Discussion

Previous reviews have demonstrated that measuring contact with a health service is not sufficient to indicate the potential for lives saved from proven interventions (Jannati, Sadeghi et al. 2018, Amouzou, Leslie et al. 2019). As a result, adjusting contact coverage measures for QoC has become a priority goal in global health measurement. Global consensus has now coalesced around coverage cascades as a useful tool for assessing performance along the sequences of interactions between the population in need and the health system, and in identifying where bottlenecks in service provision have occurred (Amouzou, Leslie et al. 2019, Marsh, Muzigaba et al. 2020). By mapping existing research against the proposed cascade (Figure 5-1), this review demonstrates that there is poor alignment between the effective coverage measures applied in previous studies and the proposed cascade measurement approach. This finding suggests the need for increased dissemination of the proposed cascade approach to promote greater uptake.

We examined the dimensions of QoC that have been used to adjust population-level contact coverage measures and how the items used to construct the measures relate to the steps of the coverage cascade outlined by the Effective Coverage Think Tank Group. We found limited consistency in the definition and construction of effective coverage measures for preventative and curative services and interventions from childbirth through to children up to nine years old in LMICs. An exception was the five studies which examined provision of micronutrient powders or complementary foods; these studies conceptualised effective coverage based on the same four steps (message coverage, contact coverage, partial coverage and effective coverage) defined using similar items collected through household surveys (Aaron, Strutt et al. 2016, Leyvraz, Rohner et al. 2016, Leyvraz, Wirth et al. 2016, Nguyen, Poonawala et al. 2016, Leyvraz, David-Kigaru et al. 2018). The uniformity in approach is likely due to being undertaken by the same group of authors.

Mapping the measures against the coverage cascade we identified three key areas of divergence: i) different approaches to combining individual interventions when a study examined a service package; ii) adjustments to different steps of the coverage cascade for the same health services or interventions; and iii) different approaches to defining and constructing the QoC measure. These differences limit comparability of effective coverage measures over time and place, and thus the ability to use these measures to track progress at national and global levels.

Effective coverage measures have been generated for single interventions or several interventions combined, reducing comparability across measures of similar interventions or health services. These differences may be driven by the focus of the study, which, in turn, may have been guided by national priorities and data availability (Jannati, Sadeghi et al. 2018).

The type and number of adjustments made to contact coverage measures also varied. The majority of studies adjusted contact coverage for one step; only three measures adjusted for all three steps described in the Effective Think Tank Group coverage cascade to generate a quality-adjusted measure (inputs, interventions and process quality) (Nesbitt, Lohela et al. 2013, Larson, Vail et al. 2017, Murphy, Gathara et al. 2018). The choice of adjustment is likely to be driven by data availability, the intervention type or country priorities. However, even where studies had relevant data available they did not always make adjustments for all cascade steps. For example, the SPA includes a facility inventory module and in some countries additional modules on health worker interview, direct observation of care and patient exit interviews. Two studies (one childbirth and one sick child care) used SPA data to adjust for interventions and process quality steps but did not adjust for inputs (Leslie, Malata et al. 2017, Joseph, Piwoz et al. 2020).

Approaches taken to construct the individual adjusted coverage measures were highly variable, both in terms of the number of items used and the methods for generating a summary measure. This in part reflects wider challenges associated with measurement of QoC. Quality is a complex construct that represents multiple dimensions with few standardised and validated measures (Hanefeld, Powell-Jackson et al. 2017). Two studies that defined thresholds for minimum quality both commented that thresholds have not been empirically defined and consequently the cut offs selected were somewhat arbitrary (Larson, Vail et al. 2017, Koulidiati, Nesbitt et al. 2018).

Data availability has considerable implications for the feasibility of constructing coverage cascades. Of the five steps beyond contact coverage, adjustment for the process quality step was the most common, based on responder's self-reports in household surveys. Adjustment for inputs, on the other hand, was restricted to interventions delivered at a facility and only feasible where studies also included a health facility assessment. Reports from health facility assessments such as the SPA and SARA are not available in all countries, for example, Nigeria has no SPA or SARA data despite having one of the highest maternal and child mortality rates globally (WHO , WHO). Further, nationally representative facility surveys are only conducted periodically and are often not coordinated with other household surveys. A study conducted in Rwanda used four rounds of DHS between 2000 and 2015, the authors noted they did not include SPA data as it was conducted in 2006 only (Hategeka, Arsenault et al. 2020). The health facility assessments themselves have limitations as in the case of the standard SPA protocol direct observations of care are only collected for three services (antenatal care, family planning and sick child care) (Sheffel, Karp et al. 2018). This review identified limited evidence of the use of routine data. Only one study conducted in Mexico used routine health information systems to estimate quality of services received (Leslie, Doubova et al. 2019). That study adjusted for health outcomes (adverse outcomes or mortality) only and was the only study included to do so.

Each of these areas of heterogeneity in definition and construction of QoC influenced the effective coverage estimates. Heterogeneity is not limited to the issues identified in this review: a recent review of methodological considerations for linking household and health facility data also identified a lack of standardisation in approaches to linking (Carter, Leslie et al. 2021).

5.5.1 Limitations of the evidence

No studies were identified among children aged five to nine years, reflecting the lack of data available to measure coverage of interventions for this age-group (Requejo, Diaz et al. 2020); and only one study examined curative interventions among sick neonates, again reflecting a lack of data but also indicative of the measurement challenges inherent for

emergency care for this population group (Moxon, Ruysen et al. 2015, Marchant, Bryce et al. 2016, Moller, Newby et al. 2018).

All studies identified were undertaken for research purposes and there was limited evidence of whether and how these measures were used by decision makers. Studies that link health facility assessments and population-based surveys to calculate effective coverage require complex linking methods and may not be feasible for routine analyses, outside of research purposes. One study reported that the Ministry of Health in Vietnam updated regulations based on the findings, but did not report whether or how the government engaged with the effective coverage measure (Nguyen, Poonawala et al. 2016).

5.5.2 Limitations of approach

The term 'effective coverage' is not widely used in the literature, and while we attempted to ensure search terms were as comprehensive as possible by expanding on two previous reviews (Jannati, Sadeghi et al. 2018, Amouzou, Leslie et al. 2019), it is likely that relevant studies that have conceptualised quality-adjustment in a different way may not have been identified. For example, two studies examining treatment of malaria used the term "treatment pathway" (Smith, Bruce et al. 2010, Millar, McCutcheon et al. 2014). In the field of HIV researchers have developed similar concepts, namely treatment cascades and prevention cascades (Hargreaves, Auerback et al. 2020). The challenges in searching for relevant literature highlights the complexity of this field and the need for greater standardisation in terminology. Further, additional relevant studies may have been missed as search terms and literature were restricted to English and we did not systematically search for any grey literature, although we consulted with members of the CHAT group for any additional documents to include in the review. Several authors were members of the Effective Coverage Think Tank group so we did not think a systematic search of the grey literature would yield a significant number of articles that we would not have already included in the review. The scope of the study was limited to interventions from childbirth to children up to nine years of age, and as such does not capture interventions across the whole continuum of MNCAHN care.

The mapping of items against the coverage cascade highlighted a lack of clarity in the definitions of the individual cascade steps. In the Effective Coverage Think Tank cascade, the inclusion of 'intervention' as a distinct step from service contact was not in line with much of the literature which most frequently use intervention coverage to refer to a crude coverage measure. Likewise, the use of the term 'quality' as a standalone step in the cascade is confusing given the wider conceptualisation of quality as a multi-dimensional concept (Donabedian 1988). We found the distinction between the intervention and quality steps of the cascade was not clear cut; we differentiated between these two steps during data

extraction based on whether the intervention delivered resulted in a direct health benefit or whether it enhanced the interaction. In most cases, studies that collected data falling under these two steps referred to items as 'process indicators'; items we have mapped under these two steps might therefore be misclassified.

5.5.3 Next steps

If effective coverage measures are to have greater utility in tracking progress and driving change in countries, then further work is needed to implement the coverage cascade approach and harmonised methods for measuring each step of the cascade (after the cascade is refined to address the problems noted above on the use of the term quality and intervention). In the short term, there is a need for greater transparency and more specificity in the reporting of effective coverage measures. Future studies should provide more information on how the effective coverage metrics were constructed, including identifying the items and methods used to construct measures and the rationale for those choices. In the longer term, there is a need for greater harmonisation and consensus on standard indicators, which requires global guidance on best practice. The full mapping of the items against the coverage cascade, presented in Tables S4 to S12 in Appendix 2, provides a useful starting point for future research and research guidance.

Second, while there have been shifts to generating coverage measures that have adjusted for quality, as seen in the latest DHS data – for example, added questions on the content of PNC for women - and efforts by the Mexican Ministry of Health, which has been measuring effective coverage for skilled birth attendance, services delivered to premature babies and treatment of acute respiratory infections in children to benchmark performance across States, they are not yet widely-used (Lozano, Soliz et al. 2006). To maximise the utility of effective coverage measures there is a need to explore their relevance for country decision makers so that measures are actionable, responsive to country needs, and interpretable. Finally, further research is needed to understand and improve the feasibility of measuring all steps of the cascade, including assessing the availability of relevant data and the potential for using routine data sources.

5.6 Conclusions

This is the first review to specifically examine the definitions and measurement of quality adjustments made to contact coverage measures of life-saving interventions from childbirth through to childhood to the age of nine and to map these against the coverage cascade proposed by the Effective Coverage Think Tank Group. The lack of any study on children aged five to nine years indicates the need for greater focus and visibility for this population group. The findings highlight substantial heterogeneity in both definitions of and

measurement approaches for QoC, limiting the comparability of effective coverage measures. They further demonstrate that a major shift in measurement approach will be required if the coverage cascade is to be adopted. There is a need for greater standardisation of terminology and transparency to understand how effective coverage measures are defined and the rationale for the measurement approach taken. Such progress will improve comparability for global monitoring and facilitate uptake by governments for tracking progress and targeting investments in life-saving health policies and programs.

5.7 Declarations

Acknowledgements:

We would like to thank members of the CHAT Technical Advisory Group: Ambrose Agweyu (Health Services Unit | KEMRI-Wellcome Trust Research Programme, Nairboi, Kenya), Sk Masum Billah (Maternal and Child Health Division, icddr, Dhaka, Bangladesh), Cynthia Boschi-Pinto (Universidade Federal Fluminense Rio de Janiero, Brazil), Sayaka Horiuchi (Teikyo University, Japan), Zeina Jamaluddine (American University of Beirut), Marzia Lazzerini (Institute for Maternal and Child Health IRCCS Burlo Garofolo, Tieste, Italy), Abdoulaye Maiga (Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA), Neil McKerrow (Maternal, Child and Women's Health, Dept of Health Kwazulu-Natal, South Africa), Melinda Munos (Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA) and Ralf Weigel (Witten/Herdecke University, Faculty of Health/ School of Medicine, Witten, Germany), as well as Theresa Diaz and Moise Muzigaba (Department of Maternal Newborn, Child and Adolescent Health and Ageing, World Health Organization) and Zelee Hill (University College London, London UK) for their review of earlier drafts.

The authors alone are responsible for the views expressed in this Article, and they do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated.

Funding:

JE undertook this work as part of the IDEAS (Informed Decisions for Actions to improve maternal and newborn health) project. IDEAS is funded through a grant from the Bill & Melinda Gates Foundation to the London School of Hygiene & Tropical Medicine. Gates Global Health Grant Number: OPP1149259/INV-007644. PG was funded under a USAID grant to WHO [US Department of State (68023)].

This work was supported, in whole or in part, by the Bill & Melinda Gates Foundation [OPP1149259/INV-007644]. Under the grant conditions of the Foundation, a Creative Commons Attribution 4.0 Generic License has already been assigned to the Author Accepted Manuscript version that might arise from this submission.

The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

Authorship contributions:

JE, PG, TM, JS, JHR, and KLS conceptualised the study. JE and PAG contributed equally to the systematic review and are joint first authors. JE and PAG conducted the literature

search, review and synthesis of papers and prepared the initial draft. All authors contributed to multiple revisions and approved the paper.

Competing interests:

The authors completed the Unified Competing Interest form at ww.icmje.org/coi_disclosure.pdf (available upon request from the corresponding author), and declare no conflicts of interest.

5.8 References

"Child Health Accountability Tracking Technical Advisory Group (CHAT) website." online: https://www.who.int/data/maternal-newborn-child-adolescent-ageing/advisory-groups/chat [accessed on 22 August 2021].

"Mother and Newborn Information for Tracking Outcomes and Results (MoNITOR) website." online: https://www.who.int/data/maternal-newborn-child-adolescent-ageing/advisory-groups/monitor [accessed on 3 September 2021].

Aaron, G. J., N. Strutt, N. A. Boateng, E. Guevarra, K. Siling, A. Norris, S. Ghosh, M. Nyamikeh, A. Attiogbe, R. Burns, E. Foriwa, Y. Toride, S. Kitamura, K. Tano-Debrah, D. Sarpong and M. Myatt (2016). "Assessing Program Coverage of Two Approaches to Distributing a Complementary Feeding Supplement to Infants and Young Children in Ghana." PLoS One **11**(10): e0162462.

Amouzou, A., H. H. Leslie, M. Ram, M. Fox, S. S. Jiwani, J. Requejo, T. Marchant, M. K. Munos, L. M. E. Vaz, W. Weiss, C. Hayashi and T. Boerma (2019). "Advances in the measurement of coverage for RMNCH and nutrition: from contact to effective coverage." BMJ Glob Health **4**(Suppl 4): e001297.

Baker, U., S. Peterson, T. Marchant, G. Mbaruku, S. Temu, F. Manzi and C. Hanson (2015). "Identifying implementation bottlenecks for maternal and newborn health interventions in rural districts of the United Republic of Tanzania." Bull World Health Organ **93**(6): 380-389.

Boerma, T., J. Requejo, C. G. Victora, A. Amouzou, A. George, I. Agyepong, C. Barroso, A. J. D. Barros, Z. A. Bhutta, R. E. Black, J. Borghi, K. Buse, L. C. Aguirre, M. Chopra, D. Chou, Y. Chu, M. Claeson, B. Daelmans, A. Davis, J. DeJong, T. Diaz, S. El Arifeen, F. Ewerling, M. Fox, S. Gillespie, J. Grove, T. Guenther, A. Haakenstad, A. R. Hosseinpoor, S. Hounton, L. Huicho, T. Jacobs, S. Jiwani, Y. Keita, R. Khosla, M. E. Kruk, T. Kuo, C. Kyobutungi, A. Langer, J. E. Lawn, H. Leslie, M. Liang, B. Maliqi, A. Manu, H. Masanja, T. Marchant, P. Menon, A. C. Moran, O. J. Mujica, D. Nambiar, K. Ohiri, L. A. Park, G. C. Patton, S. Peterson, E. Piwoz, K. Rasanathan, A. Raj, C. Ronsmans, G. Saad-Haddad, M. L. Sabin, D. Sanders, S. M. Sawyer, I. C. M. da Silva, N. S. Singh, K. Somers, P. Spiegel, H. Tappis, M. Temmerman, L. M. E. Vaz, R. R. Ved, L. P. Vidaletti, P. Waiswa, F. C. Wehrmeister, W. Weiss, D. You and S. Zaidi (2018). "Countdown to 2030: tracking progress towards universal coverage for reproductive, maternal, newborn, and child health." Lancet **391**(10129): 1538-1548.

Carter, E. D., H. H. Leslie, T. Marchant, A. Amouzou and M. K. Munos (2021). "Methodological considerations for linking household and healthcare provider data for estimating effective coverage: a systematic review." BMJ Open **11**(8): e045704.

Carter, E. D., M. Ndhlovu, T. P. Eisele, E. Nkhama, J. Katz and M. Munos (2018). "Evaluation of methods for linking household and health care provider data to estimate effective coverage of management of child illness: results of a pilot study in Southern Province, Zambia." J Glob Health **8**(1): 010607.

Carvajal-Aguirre, L., A. Amouzou, V. Mehra, M. Ziqi, N. Zaka and H. Newby (2017). "Gap between contact and content in maternal and newborn care: An analysis of data from 20 countries in sub-Saharan Africa." J Glob Health **7**(2): 020501.

Cumpston, M., T. Li, M. J. Page, J. Chandler, V. A. Welch, J. P. Higgins and J. Thomas (2019). "Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions." Cochrane Database Syst Rev **10**: Ed000142.

Donabedian, A. (1988). "The quality of care. How can it be assessed?" Jama **260**(12): 1743-1748.

GBD 2019 Universal Health Coverage Collaborators (2020). "Measuring universal health coverage based on an index of effective coverage of health services in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019." Lancet **396**(10258): 1250-1284.

Grant, M. J. and A. Booth (2009). "A typology of reviews: an analysis of 14 review types and associated methodologies." Health information & libraries journal **26**(2): 91-108.

Grove, J., M. Claeson, J. Bryce, A. Amouzou, T. Boerma, P. Waiswa and C. Victora (2015). "Maternal, newborn, and child health and the Sustainable Development Goals--a call for sustained and improved measurement." Lancet **386**(10003): 1511-1514.

Hanefeld, J., T. Powell-Jackson and D. Balabanova (2017). "Understanding and measuring quality of care: dealing with complexity." Bull World Health Organ **95**(5): 368-374.

Hargreaves, J., J. Auerback, B. Hensen and S. Gregson (2020). "Special Issue: Data-driven HIV prevention: the HIV prevention cascade and beyond." Journal of the International Aids Society **23**(S3).

Hategeka, C., C. Arsenault and M. E. Kruk (2020). "Temporal trends in coverage, quality and equity of maternal and child health services in Rwanda, 2000-2015." BMJ Glob Health **5**(11): e002768.

Jannati, A., V. Sadeghi, A. Imani and M. Saadati (2018). "Effective coverage as a new approach to health system performance assessment: a scoping review." BMC Health Serv Res **18**(1): 886.

Joseph, N. T., E. Piwoz, D. Lee, A. Malata and H. H. Leslie (2020). "Examining coverage, content, and impact of maternal nutrition interventions: the case for quality-adjusted coverage measurement." J Glob Health **10**(1): 010501.

Kanyangarara, M., V. B. Chou, A. A. Creanga and N. Walker (2018). "Linking household and health facility surveys to assess obstetric service availability, readiness and coverage: evidence from 17 low- and middle-income countries." J Glob Health **8**(1): 010603.

Kemp, C. G., R. Sorensen, N. Puttkammer, R. Grand'Pierre, J. G. Honoré, L. Lipira and C. Adolph (2018). "Health facility readiness and facility-based birth in Haiti: a maximum likelihood approach to linking household and facility data." J Glob Health Rep **2**: e2018023.

Koulidiati, J. L., R. C. Nesbitt, N. Ouedraogo, H. Hien, P. J. Robyn, P. Compaoré, A. Souares and S. Brenner (2018). "Measuring effective coverage of curative child health services in rural Burkina Faso: a cross-sectional study." BMJ Open **8**(5): e020423.

Kruk, M. E., A. D. Gage, C. Arsenault, K. Jordan, H. H. Leslie, S. Roder-DeWan, O. Adeyi, P. Barker, B. Daelmans and S. V. Doubova (2018). "High-quality health systems in the Sustainable Development Goals era: time for a revolution." Lancet Glob Health.

Larson, E., D. Vail, G. M. Mbaruku, R. Mbatia and M. E. Kruk (2017). "Beyond utilization: measuring effective coverage of obstetric care along the quality cascade." Int J Qual Health Care **29**(1): 104-110.

Leslie, H. H., S. V. Doubova and R. Pérez-Cuevas (2019). "Assessing health system performance: effective coverage at the Mexican Institute of Social Security." Health Policy Plan **34**(Supplement_2): ii67-ii76.

Leslie, H. H., A. Malata, Y. Ndiaye and M. E. Kruk (2017). "Effective coverage of primary care services in eight high-mortality countries." BMJ Glob Health **2**(3): e000424.

Leyvraz, M., D. M. David-Kigaru, C. Macharia-Mutie, G. J. Aaron, M. Roefs and A. Tumilowicz (2018). "Coverage and Consumption of Micronutrient Powders, Fortified Staples, and Iodized Salt Among Children Aged 6 to 23 Months in Selected Neighborhoods of Nairobi County, Kenya." Food Nutr Bull **39**(1): 107-115.

Leyvraz, M., F. Rohner, A. G. Konan, L. J. Esso, B. A. Woodruff, A. Norte, A. F. Adiko, B. Bonfoh and G. J. Aaron (2016). "High Awareness but Low Coverage of a Locally Produced

Fortified Complementary Food in Abidjan, Côte d'Ivoire: Findings from a Cross-Sectional Survey." PLoS One **11**(11): e0166295.

Leyvraz, M., J. P. Wirth, B. A. Woodruff, R. Sankar, P. R. Sodani, N. D. Sharma and G. J. Aaron (2016). "High Coverage and Utilization of Fortified Take-Home Rations among Children 6-35 Months of Age Provided through the Integrated Child Development Services Program: Findings from a Cross-Sectional Survey in Telangana, India." PLoS One **11**(10): e0160814.

Lozano, R., P. Soliz, E. Gakidou, J. Abbott-Klafter, D. M. Feehan, C. Vidal, J. P. Ortiz and C. J. Murray (2006). "Benchmarking of performance of Mexican states with effective coverage." Lancet **368**(9548): 1729-1741.

Marchant, T., J. Bryce, C. Victora, A. C. Moran, M. Claeson, J. Requejo, A. Amouzou, N. Walker, T. Boerma and J. Grove (2016). "Improved measurement for mothers, newborns and children in the era of the Sustainable Development Goals." J Glob Health **6**(1): 010506.

Marchant, T., R. D. Tilley-Gyado, T. Tessema, K. Singh, M. Gautham, N. Umar, D. Berhanu, S. Cousens and J. R. Armstrong Schellenberg (2015). "Adding content to contacts: measurement of high quality contacts for maternal and newborn health in Ethiopia, north east Nigeria, and Uttar Pradesh, India." PLoS One **10**(5): e0126840.

Marsh, A. D., M. Muzigaba, T. Diaz, J. Requejo, D. Jackson, D. Chou, J. A. Cresswell, R. Guthold, A. C. Moran, K. L. Strong, A. Banerjee and A. Soucat (2020). "Effective coverage measurement in maternal, newborn, child, and adolescent health and nutrition: progress, future prospects, and implications for quality health systems." Lancet Glob Health **8**(5): e730-e736.

Millar, K. R., J. McCutcheon, E. H. Coakley, W. Brieger, M. A. Ibrahim, Z. Mohammed, A. Bassi and W. Sambisa (2014). "Patterns and predictors of malaria care-seeking, diagnostic testing, and artemisinin-based combination therapy for children under five with fever in Northern Nigeria: a cross-sectional study." Malar J **13**: 447.

Mmanga, K., T. E. Mwenyenkulu, O. Nkoka and P. A. M. Ntenda (2021). "Tracking immunization coverage, dropout and equity gaps among children ages 12-23 months in Malawi - bottleneck analysis of the Malawi Demographic and Health Survey." Int Health.

Mokdad, A. H., M. C. Gagnier, K. E. Colson, E. Dansereau, P. Zúñiga-Brenes, D. Ríos-Zertuche, A. Haakenstad, C. K. Johanns, E. B. Palmisano, B. Hernandez and E. Iriarte (2015). "Missed Opportunities for Measles, Mumps, and Rubella (MMR) Immunization in Mesoamerica: Potential Impact on Coverage and Days at Risk." PLoS One **10**(10): e0139680.

Moller, A.-B., H. Newby, C. Hanson, A. Morgan, S. El Arifeen, D. Chou, T. Diaz, L. Say, I. Askew and A. C. Moran (2018). "Measures matter: A scoping review of maternal and newborn indicators." PLoS ONE **13**(10): e0204763.

Moller, A. B., J. H. Patten, C. Hanson, A. Morgan, L. Say, T. Diaz and A. C. Moran (2019). "Monitoring maternal and newborn health outcomes globally: a brief history of key events and initiatives." Trop Med Int Health **24**(12): 1342-1368.

Moran, A. C., A. B. Moller, D. Chou, A. Morgan, S. El Arifeen, C. Hanson, L. Say, T. Diaz, I. Askew and A. Costello (2018). "'What gets measured gets managed': revisiting the indicators for maternal and newborn health programmes." Reprod Health **15**(1): 19.

Moxon, S. G., H. Ruysen, K. J. Kerber, A. Amouzou, S. Fournier, J. Grove, A. C. Moran, L. M. Vaz, H. Blencowe, N. Conroy, A. Gulmezoglu, J. P. Vogel, B. Rawlins, R. Sayed, K. Hill, D. Vivio, S. A. Qazi, D. Sitrin, A. C. Seale, S. Wall, T. Jacobs, J. Ruiz Pelaez, T. Guenther, P. S. Coffey, P. Dawson, T. Marchant, P. Waiswa, A. Deorari, C. Enweronu-Laryea, S. Arifeen, A. C. Lee, M. Mathai and J. E. Lawn (2015). "Count every newborn; a measurement improvement roadmap for coverage data." BMC Pregnancy Childbirth **15 Suppl 2**: S8.

Munos, M. K., A. Maiga, M. Do, G. L. Sika, E. D. Carter, R. Mosso, A. Dosso, A. Leyton and S. M. Khan (2018). "Linking household survey and health facility data for effective coverage measures: a comparison of ecological and individual linking methods using the Multiple Indicator Cluster Survey in Côte d'Ivoire." J Glob Health **8**(2): 020803.

Murphy, G. A. V., D. Gathara, J. Mwachiro, N. Abuya, J. Aluvaala and M. English (2018). "Effective coverage of essential inpatient care for small and sick newborns in a high mortality urban setting: a cross-sectional study in Nairobi City County, Kenya." BMC Med **16**(1): 72.

Murray, C. J. L. and D. B. Evans (2003). Technical Consultation on Effective Coverage in Health Systems. Health systems performance assessment : debates, methods and empiricism. Geneva, World Health Organization**:** 125-134.

Nesbitt, R. C., T. J. Lohela, A. Manu, L. Vesel, E. Okyere, K. Edmond, S. Owusu-Agyei, B. R. Kirkwood and S. Gabrysch (2013). "Quality along the continuum: a health facility assessment of intrapartum and postnatal care in Ghana." PLoS One **8**(11): e81089.

Ng, M., N. Fullman, J. L. Dieleman, A. D. Flaxman, C. J. L. Murray and S. S. Lim (2014). "Effective Coverage: A Metric for Monitoring Universal Health Coverage." PLoS Med **11**(9): e1001730.

Nguhiu, P. K., E. W. Barasa and J. Chuma (2017). "Determining the effective coverage of maternal and child health services in Kenya, using demographic and health survey data

sets: tracking progress towards universal health coverage." Trop Med Int Health **22**(4): 442-453.

Nguyen, M., A. Poonawala, M. Leyvraz, J. Berger, D. Schofield, T. T. Nga, T. K. Van, T. B. Hoa do and F. T. Wieringa (2016). "A Delivery Model for Home Fortification of Complementary Foods with Micronutrient Powders: Innovation in the Context of Vietnamese Health System Strengthening." Nutrients **8**(5).

Nguyen, P. H., L. Q. Khương, P. Pramanik, S. M. Billah, P. Menon, E. Piwoz and H. H. Leslie (2021). "Effective coverage of nutrition interventions across the continuum of care in Bangladesh: insights from nationwide cross-sectional household and health facility surveys." BMJ Open **11**(1): e040109.

Okawa, S., M. Gyapong, H. Leslie, A. Shibanuma, K. Kikuchi, F. Yeji, C. Tawiah, S. Addei, K. Nanishi, A. R. Oduro, S. Owusu-Agyei, E. Ansah, G. Q. Asare, J. Yasuoka, A. Hodgson and M. Jimba (2019). "Effect of continuum-of-care intervention package on improving contacts and quality of maternal and newborn healthcare in Ghana: a cluster randomised controlled trial." BMJ Open **9**(9): e025347.

Okawa, S., H. H. Win, H. H. Leslie, K. Nanishi, A. Shibanuma, P. P. Aye and M. Jimba (2019). "Quality gap in maternal and newborn healthcare: a cross-sectional study in Myanmar." BMJ Glob Health **4**(2): e001078.

Page, M. J., J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan, R. Chou, J. Glanville, J. M. Grimshaw, A. Hróbjartsson, M. M. Lalu, T. Li, E. W. Loder, E. Mayo-Wilson, S. McDonald, L. A. McGuinness, L. A. Stewart, J. Thomas, A. C. Tricco, V. A. Welch, P. Whiting and D. Moher (2021). "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews." BMJ **372**: n71.

Requejo, J., T. Diaz, L. Park, D. Chou, A. Choudhury, R. Guthold, D. Jackson, A.-B. Moller, J.-P. Monet, A. C. Moran, L. Say, K. L. Strong and A. Banerjee (2020). "Assessing coverage of interventions for reproductive, maternal, newborn, child, and adolescent health and nutrition." BMJ **368**: l6915.

Requejo, J. H., H. Newby and J. Bryce (2013). "Measuring coverage in MNCH: challenges and opportunities in the selection of coverage indicators for global monitoring." PLoS Med **10**(5): e1001416.

Sharma, J., H. H. Leslie, F. Kundu and M. E. Kruk (2017). "Poor Quality for Poor Women? Inequities in the Quality of Antenatal and Delivery Care in Kenya." PLoS One **12**(1): e0171236.

Sheff, M. C., A. A. Bawah, P. O. Asuming, P. Kyei, M. Kushitor, J. F. Phillips and S. P. Kachur (2020). "Evaluating health service coverage in Ghana's Volta Region using a modified Tanahashi model." Glob Health Action **13**(1): 1732664.

Sheffel, A., C. Karp and A. A. Creanga (2018). "Use of Service Provision Assessments and Service Availability and Readiness Assessments for monitoring quality of maternal and newborn health services in low-income and middle-income countries." BMJ Glob Health **3**(6): e001011.

Shengelia, B., A. Tandon, O. B. Adams and C. J. L. Murray (2005). "Access, utilization, quality, and effective coverage: An integrated conceptual framework and measurement strategy." Soc Sci Med **61**(1): 97-109.

Shibanuma, A., F. Yeji, S. Okawa, E. Mahama, K. Kikuchi, C. Narh, Y. Enuameh, K. Nanishi, A. Oduro, S. Owusu-Agyei, M. Gyapong, G. Q. Asare, J. Yasuoka, E. K. Ansah, A. Hodgson and M. Jimba (2018). "The coverage of continuum of care in maternal, newborn and child health: a cross-sectional study of woman-child pairs in Ghana." BMJ Glob Health **3**(4): e000786.

Smith, L. A., J. Bruce, L. Gueye, A. Helou, R. Diallo, B. Gueye, C. Jones and J. Webster (2010). "From fever to anti-malarial: the treatment-seeking process in rural Senegal." Malar J **9**(1): 333.

Tanahashi, T. (1978). "Health service coverage and its evaluation." Bull World Health Organ **56**(2): 295-303.

The Endnote team (2013). "EndNote. 9th ed." Philadelphia, PA: Clarivate Analytics.

The Partnership for Maternal Health, Newborn and Child Health and Aga Khan University (2011). "Essential Interventions, Commodities and Guidelines for Reproductive, Maternal, Newborn and Child Health. A global review of the key interventions related to reproductive, maternal, newborn and child health." Geneva, Switzerland: PMNCH.

The World Bank (2020). "World Bank Country and Lending Groups: Country Classification." online: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups [accessed on 1 November 2021].

Tricco, A. C., E. Langlois and S. E. Straus (2017). "Rapid reviews to strengthen health policy and systems: a practical guide." Geneva: World Health Organization.

Tunçalp, Ö., W. Were, C. MacLennan, O. Oladapo, A. Gülmezoglu, R. Bahl, B. Daelmans, M. Mathai, L. Say, F. Kristensen, M. Temmerman and F. Bustreo (2015). "Quality of care for pregnant women and newborns—the WHO vision." Bjog **122**(8): 1045-1049.

Wang, W., L. Mallick, C. Allen and T. Pullum (2019). "Effective coverage of facility delivery in Bangladesh, Haiti, Malawi, Nepal, Senegal, and Tanzania." PLoS One **14**(6): e0217853.

WHO "The Global Health Observatory: Maternal mortality ratio (per 100 000 live births)." online: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/maternal-mortality-ratio-(per-100-000-live-births) [accessed on 11 June 2021].

WHO "The Global Health Observatory: Under-five mortality rate (probability of dying by age 5 per 1000 live births)." online: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/under-five-mortality-rate-(probability-of-dying-by-age-5-per-1000-live-births) [accessed on 11 June 2021].

WHO "SDG 3: Ensure healthy lives and promote wellbeing for all at all ages." World Health Organisation. online: https://www.who.int/sdg/targets/en/ [accessed on 12 July 2020].

WHO (2001). "Background paper for the Technical Consultation on Effective Coverage of Health Systems, 27-29 August 2001, Rio de Janeiro, Brazil." online: http://citeseerx.ist.psu.edu/viewdoc/download?rep=rep1&type=pdf&doi=10.1.1.111.1239 [accessed on 31 May 2020].

WHO (2016). "Standards for improving quality of maternal and newborn care in health facilities." World Health Organization: Geneva.

WHO and The World Bank (2015). "Tracking Universal Health Coverage. First Global Monitoring Report." Geneva: World Health Organization.

WHO, UNICEF, UNFPA and World Bank Group and the United Nations Population Division (2019). "Maternal mortality: Levels and trends. 2000 to 2017." Geneva: World Health Organization.

Willey, B., P. Waiswa, D. Kajjo, M. Munos, J. Akuze, E. Allen and T. Marchant (2018). "Linking data sources for measurement of effective coverage in maternal and newborn health: what do we learn from individual- vs ecological-linking methods?" J Glob Health **8**(1): 010601.

6 Objective 3: estimating effective coverage of childbirth in Gombe

To understand the feasibility and utility of constructing effective coverage of childbirth care using data sources typically available in decision makers in Gombe, I estimated the prevalence of effective coverage of facility based childbirth, using two different sources of facility data: comprehensive facility assessment project data and DHIS2.

The results of the analysis were published in PLOS Global Public Health:

Exley, J., et al. (2022). "Operationalising effective coverage measurement of facility based childbirth in Gombe State; a comparison of data sources." PLOS Global Public Health.

The manuscript is presented in the rest of this chapter and the supplementary material accompanying the manuscript is presented in appendix 3.

Operationalising effective coverage measurement of facility based childbirth in Gombe State; a comparison of data sources

Authors: Josephine Exley[1*], Antoinette Bhattacharya[1], Claudia Hanson[1,2], Abdulrahman Shuaibu[3], Nasir Umar[1] and Tanya Marchant[1]

Author affiliations:

[1] Department of Disease Control, London School of Hygiene & Tropical Medicine, UK

[2] Department of Public Health Sciences–Global Health, Karolinska Institutet, Stockholm, Sweden

[3] The Executive Secretary, Gombe State Primary Health Care Development Agency, Nigeria

* Corresponding author

E-mail: Josephine.Exley@lshtm.ac.uk

Word count: 3,928

6.1 Abstract

Estimating effective coverage of childbirth care requires linking population based data sources to health facility data. For effective coverage to gain widespread adoption there is a need to focus on the feasibility of constructing these measures using data typically available to decision makers in low resource settings. We estimated effective coverage of childbirth care in Gombe State, northeast Nigeria, using two different combinations of facility data sources and examined their strengths and limitations for decision makers. Effective coverage captures information on four steps: access, facility inputs, receipt of interventions and process quality. We linked data from the 2018 Nigerian Demographic and Health Survey (NDHS) to two sources of health facility data: (1) comprehensive health facility survey data generated by a research project; and (2) District Health Information Software 2 (DHIS2). For each combination of data sources, we examined which steps were feasible to calculate, the size of the drop in coverage between steps and the resulting estimate of effective coverage. Analysis included 822 women with a recent live birth, 30% of whom attended a facility for childbirth. Effective coverage was low: 2% based on the project data and less than 1% using the DHIS2. Linking project data with NDHS, it was feasible to measure all four steps; using DHIS2 it was possible to estimate three steps: no data was available to measure process quality. The provision of high quality care is suboptimal in this high mortality setting where access and facility readiness to provide care, crucial foundations to the provision of high quality of care, have not yet been met. This study demonstrates that partial effective coverage measures can be constructed from routine data combined with nationally representative surveys. Advocacy to include process of care indicators in facility summary reports could optimise this data source for decision making.

6.2 Introduction

Ensuring access to high quality maternal and newborn care is a global priority in efforts to reduce preventable mortality and morbidity [1-5]. Measuring the quality of care delivered to women and newborns is central to supporting this goal, and effective coverage measures are now recommended as best practice [6-9]. Effective coverage combines need, use and quality of care into a single metric to estimate the proportion of a population in need of a service that had a positive health outcome from that service.

There is emerging consensus that effective coverage of maternal, newborn and child health (MNCH) is best conceptualised using a care cascade, which outlines six sequential steps that the target population is anticipated to have to move through to achieve the intended health benefit: 1) service contact; 2) input-adjusted coverage; 3) intervention-adjusted coverage; 4) process quality-adjusted coverage; 5) user-adherence adjusted coverage; and 6) outcome-adjusted coverage [7,10]. For health services, such as childbirth care, during which multiple interventions are delivered and the direct health impacts of specific interventions is challenging to attribute, process quality-adjusted coverage is the recommended measure of effective coverage.

Despite consensus on the concept, research on how to best operationalise the cascade, including which data sets and indicators to use, is limited [11-14]. A recent review of effective coverage of MNCH interventions found no consistent approach to the adjustments made to contact coverage, and examples in the literature were frequently limited to the use of primary sample survey data or use of open-access nationally representative surveys [15]; the review identified only one study that used data from health management information systems (HMIS) to estimate effective coverage of childbirth based on health outcomes [16]. To inform decisions at the country level there is a need to examine the extent to which meaningful effective coverage measures can be developed from alternative data sources that are routinely available to decision makers such as administrative or HMIS data [7].

This study aimed to address this issue by demonstrating whether and how the effective coverage of childbirth care can be generated using two different health facility data sources to adjust population-level data on contact coverage in Gombe State, northeast Nigeria. First, using comprehensive health facility survey data generated by a research project and second we examined the feasibility of replicating that measure using only routine data sources typically available to decisions makers.

6.3 Materials and Methods

6.3.1 Ethics statement

Ethical approval for this study was obtained from the Nigerian National Health Research Ethics Committee (NHREC/01/01/2007), the State Ministry of Health Gombe State (ADM/S/658/Vol. II/66) and the London School of Hygiene & Tropical Medicine (22330). For the health facility project specific data, all potential participants were provided with a study information sheet and a consent form in English and Hausa. The in-charge of each facility gave written informed consent for the facility survey; written consent was also obtained from the birth attendant interviewed and women observed. Participation was voluntary and participants were free to withdraw at any time.

6.3.2 Study setting

Gombe State is a predominantly rural (80%) and sparsely populated state in northeast Nigeria [17]. It is made up of 11 local government areas (LGAs) and 114 wards; about half of the population live in the State's central belt, made up of four LGAs.

The northeast region of Nigeria has some of the highest maternal and newborn death rates globally, estimated at 1,549 per 100,000 live births in 2015 and 33 per 1,000 live births in 2017, respectively [18,19]. Healthcare is predominantly delivered via a network of rural primary healthcare clinics (PHCs) run by the Gombe State Primary Healthcare Development Agency (GSPHCDA). In 2017, 460 PHCs and 26 referral facilities provided intrapartum services [20], mainly delivered by community health extension workers (CHEWs), junior CHEWs and community health officers.

Between 2016 and 2019, the GSPHCDA led a maternal and newborn health partnership designed to implement a package of evidence-based interventions to improve access, use and quality of maternal and newborn health services, across the 11 LGAs of Gombe State [21-24]. Throughout this period, actions were taken to strengthen the use of HMIS data for decision making [25], plus detailed primary data was collected to track progress in access to, and supply of, quality maternal and newborn health services.

6.3.3 Data sources

Generating effective coverage of childbirth requires linking care seeking data collected through population based data sources with information from health facilities on the quality of the interventions provided [11]. Two sources of population data representative at the national and State levels in Nigeria had potential for this analysis: the Nigerian Demographic and Health Survey (NDHS) last conducted in 2018 and the Multiple Indicator Cluster Survey (MICS) last carried out in 2016/2017. We used NDHS given it was undertaken most recently. Two sources of facility data were accessed: 1) comprehensive health facility survey data

collected as part of the partnership to improve maternal and newborn health services [24]; and 2) HMIS data available through monthly facility reports from District Health Information Software 2 (DHIS2). Previous studies of effective coverage of childbirth have used service provision assessment (SPA) and service availability and readiness assessment (SARA) [12, 26-31], but neither of these surveys have been undertaken in Nigeria.

Population data

The NDHS is conducted every five years using a two-stage stratified cluster sample, designed to be representative at the national and state level [32]. The household survey included face-to-face interviews with all women aged 15 to 49 years in the sampled households, both permanent residents and visitors who stayed in the household the night before the survey. Data was extracted from the birth record for all women in Gombe State aged 15 to 49 who reported a live birth and the place of care seeking in the five years preceding the survey.

Project specific health facility data

We used health facility survey data from August 2019. Data collection methods are reported in detail elsewhere [33]. Briefly, a health facility survey was completed in a sample of 98 PHCs across the 114 wards of Gombe State and all 18 referral facilities in the State. The health facility survey comprised a readiness assessment that included a checklist of staff, equipment, drugs, and infrastructure items present on the day of survey; data extraction from facility registers on the number and outcomes of all births during the previous six-months; interviews with birth attendants; and the observation of births in a sub-set of facilities. For the purpose of this analysis, facilities handling fewer than one delivery per week (n=11) were excluded on the grounds that they are not representative of the typical facility women seek childbirth care from.

During the facility survey, observations of childbirth were completed in the 10 PHCs with the highest number of births recorded in the maternity register [34,35]. Observations were completed by clinically trained female data collectors (local midwives, not employed by the facility) over a three-week period, using a structured checklist to record the processes of care and birth attendant-client interactions. The content of the checklist was developed from the USAID-funded Maternal and Child Health Integrated Program's tool for observing vaginal birth [36].

Routine health facility data

DHIS2 is an open source software platform used in more than 70 countries [37]. In Gombe, health facilities document care in 13 paper-based registers. Every month a sub-set of data in these registers is sent to the LGA health office and entered into DHIS2 [20]. Monthly

aggregated DHIS2 data related to maternal and newborn health were downloaded for the same 6-month period as the project data, from January to July 2019. As with the project data, facilities that recorded fewer than one delivery per week on average were excluded.

6.3.4 Operationalising the effective coverage cascade

We computed both effective coverage measures based on the coverage cascade steps for facility based childbirth care proposed by the Effective Coverage Think Tank Group – a group of experts convened by WHO and UNICEF [7]. Consistent with that cascade, we defined effective coverage as the proportion of all women with a recent live birth (the target population) who progressed through the subsequent four steps: 1) attended a health facility for childbirth care (service contact coverage), 2) that had appropriate inputs available (input-adjusted coverage), 3) where appropriate interventions were provided (intervention-adjusted coverage), and 4) where birth attendants followed recommended processes of care (process quality-adjusted coverage).

Table 6-1 shows how the effective coverage cascade was operationalised in the two combinations of data sources. For both cascades, the 2018 NDHS was used to estimate service contact coverage (step 1). To define the content of input-adjusted (step 2), intervention-adjusted (step 3) and process quality-adjusted coverage (step 4), we undertook a review of the literature to examine how effective coverage of childbirth has previously been defined [15]. The review identified little consistency between study definitions. We therefore selected the most frequently cited items from the literature that were also recommended by WHO [38-41]. Selected items were mapped against data available in the comprehensive project datasets and the final selection was agreed upon between the authors, including the Executive Secretary of GSPHCDA to ensure relevance to the setting. We attempted to replicate the cascade using only data typically available to decision makers; where information relating to care received was not available in DHIS2, data from NDHS was applied. No items were available in either DHIS2 or NDHS that allowed us to estimate process quality-adjusted coverage. See Table S1 in appendix 3 for full details of the individual data items used to define each step of the coverage cascade for the two approaches.

Input-adjusted measures were estimated in the respective health facility dataset (project data or DHIS2) as a binary score calculated for each facility based on: 1) all items available and functioning on the day of the survey in the project data, and 2) not experiencing stock outs of any items in the previous six months in DHIS2. Mean input-adjusted score was calculated, by facility type (PHC or referral), as the percentage of facilities with inputs available. For the project data mean intervention-adjusted and process quality-adjusted measures were estimated in the observation dataset, as the percentage of women observed

in a PHC who received all components of care. In the data typically available to decision makers, intervention-adjusted coverage was calculated based on women's self-reports in the NDHS, as the percentage of women who reported they gave birth in a facility that received all interventions. All items contributed equally to each score and missing data was treated as the item not being present.

6.3.5 Analysis

Similar to previous examples, effective coverage was calculated at the State level using ecological linking methods [11-14,31,42]. For both analysis, the NDHS was used as the basis for creating each linked dataset. Each woman in the NDHS who reported attending a facility for childbirth was assigned the mean input-adjusted score for the type of health facility (PHC or referral) that they reported seeking care from the project data and DHIS2, respectively. Additionally, for the analysis using the project data women were assigned the mean intervention-adjusted and process-adjusted score from the project data. In both analysis, women who reported delivering at home were assigned input-adjusted, intervention-adjusted and process quality-adjusted scores of 0.

From the linked datasets, we calculated each step of the cascade. The first step in the cascade, service contact coverage, was calculated as the percentage of women who reported giving birth in a facility across the State. Subsequent steps were calculated as the product of the prevalence of the step and the prevalence of the proceeding step. The analyses adjusted for the survey design using the svyset and svy commands in STATA version 15.1 (StataCorp, 2017, College Station, TX) and uncertainty of the estimates of effective coverage was assessed using the delta method [14,43]. Missed opportunities (bottlenecks) were identified from the absolute attrition in the proportion between each step of the cascade [44].

Table 6-6-1 Overview of measures used to define each step of the coverage cascade for the different data sources: (1) NDHS and project data and (2) NDHS and DHIS2

Step of the coverage cascade	(1) NDHS and project data		(2) NDHS and DHIS2	
	Measures	**Data source**	**Measures**	**Data source**
Service contact coverage	Facility based delivery among women with a live birth in last 5 yrs	NDHS	Facility based delivery among women with a live birth in last 5 yrs	NDHS
Input-adjusted coverage	Infrastructure: • Means of communicating with another facility • Electricity or alternative power supply. • Accessible toilet • Clean water Staffing: • Midwife/clinician available 24/7 Drugs & commodities: • Anticonvulsant • Baby scale • Blood pressure machine • Delivery pack • Intravenous fluids with infusion set • Infection control inside labour room • Newborn resuscitation device • Suction apparatus • Uterotonic	Health facility survey	Staffing: • Skilled birth attendant Drugs & commodities: • Anticonvulsant • Newborn resuscitation device • Uterotonic	DHIS2
Intervention coverage	• Baby weighed • Prophylactic uterotonic • Thermal care	Observations of care	• Baby weighed • Prophylactic uterotonic • Thermal care	NDHS
Process quality-adjusted coverage	• Explains procedure to woman or support person before proceeding • Maternal blood pressure taken during first stage of labour • Support person (companion) for mother present at birth • Woman recommends someone else to give birth in the health facility	Observations of care	-	-

6.4 Results

The analysis included 822 women who reported a live birth in Gombe State in the five years preceding in the NDHS (2013-2018) (Table 6-2). The project data included 105 health facilities (87 PHCs and 18 referral), which recorded handling at least one delivery per week and observations of 398 women from 10 PHCs during childbirth. The analysis using data typically available included 271 health facilities (248 PHCs and 23 referral) from DHIS2.

Table 6-1-2 Overview of study population for each dataset

Women interviewed	**NDHS – Gombe State**	
Number of women interviewed with a live birth in the last five years	823	
Number of women interviewed with a live birth in the last five years & place of birth recorded	822	
Health facilities	**Project data**	**DHIS2**
Number of PHCs	98	547
Number of PHCs with at least 1 delivery per week	87	248
Median number of births in PHCs in last 6 months (IQR)	125 (64-192)	66 (41.5-133.5)
Number of referral facilities	18	26
Number of referral facilities with at least 1 delivery per week	18	23
Median number of births in referral facilities in last 6 months (IQR)	222.5 (154-573)	239 (111-495)
Number of women observed during childbirth[1]	398	n/a

TABLE NOTE: [1] Observations were completed in 10 PHCs.

Table 6-3 presents the characteristics of all women with a recent live birth interviewed in Gombe State in the NDHS. On average women interviewed were 29 years old (sd 4.7) and had received 3 years (sd 4.7) of education. The vast majority of women reported that they were currently married and of Muslim faith; fourteen percent reported they had one child.

Table 6-1-3 Characteristics of women interviewed in Gombe State NDHS with a recent live birth and place of birth recorded, column percentage

Characteristic		% (95% CI)
Age	15-19	6.3 (4.7 – 8.4)
	20-29	45.6 (41.4 – 49.8)
	30-39	37.9 (32.2 – 41.2)
	40-49	11.2 (9.0 - 13.9)
Schooling	None	72.1 (60.1 – 81.7)
	1-7 years (primary)	10.3 (6.9 – 15.2)
	≥ 8 years (secondary)	17.5 (10.4 – 28.0)
Religion	Christian	14.0 (6.8 – 26.4)
	Muslim	85.9 (73.4 – 93.1)
Parity	1 birth	14.1 (11.8 – 16.7)
	2 births	13.1 (10.3-16.5)
	3 – 5 births	34.4 (32.4 – 36.5)
	≥ 6 births	38.4 (34.4 – 42.6)
Marital status	Currently married	94.8 (91.3 – 97.0)
	Not currently married	5.2 (3.0 – 8.7)

In the rest of the results section we first describe the composition of the four steps of the cascade in turn and then present the two effective coverage measures estimated using the different data sources.

6.4.1 Step 1: Service contact

In the NDHS for Gombe State, representing births between 2013-18, the coverage of facility based childbirth was 30%: 19% at PHCs and 11% at a referral facility. We checked for evidence of changes in facility delivery over the period of the NDHS, and found the coverage of women seeking childbirth care at a health facility to be relatively stable over the five-year period: 37% among women who delivered five years preceding the survey, 31% in the three to four years preceding, 32% in two years preceding and 27% among women who delivered in the 12 months preceding the survey.

6.4.2 Step 2: Inputs

The availability of inputs from the two facility data sources (project health facility survey or DHIS2) by facility type is presented in Table 6-4. Around a quarter of facilities were estimated to have all inputs available in the project health facility data: 18% of PHCs had all

inputs compared to 56% of referral facilities. Across all facilities communication equipment and disposable gloves was universally available. Additionally, among referral facilities electricity or light source, presence of a skilled birth attendant, blood pressure machine, delivery pack, infection control supplies, intravenous fluids and infusion set, suction apparatus and uterotonic were also universally available. The items least frequently available in PHCs were source of cleaning running water (56%) and presence of a skilled birth attendant (49%), and in referral facilities source of clean running water and newborn resuscitation equipment (both available in 78% of referral facilities).

Table 6-1-4 Facility input measures used in the summary variable that resulted in 'input-adjusted' coverage in the cascade

	Project data health facility assessment			DHIS2		
	PHC	**Referral**	**All**	**PHC**	**Referral**	**All**
Facility infrastructure						
Communication equipment	100	100	100.0	-	-	-
Electricity or light source	96.6 (92.7 – 100)	100	97.1 (94.0 – 100)	-	-	-
Source of clean running water	56.3 (45.8 – 66.79)	77.8 (58.5 – 97.1)	60.0 (48.0 – 72.0)	-	-	-
Toilet accessible to female service users	82.8 (74.8 – 90.7)	94.4 (83.8 – 100)	84.8 (76.3 – 93.2)	-	-	-
Staffing						
Skilled birth attendant	49.4 (38.9 – 60.0)	100	58.1 (49.3 – 66.8)	72.6	34.8	69.4
Supplies and commodities						
Anticonvulsants	82.8 (74.8 – 90.7)	83.3 (66.0 – 100)	82.9 (73.3 – 92.4)	34.3	65.2	36.9
Baby weighing scale	97.7 (94.5 - 100)	94.4 (83.8 - 100)	97.1 (92. 7 – 100)	-	-	-
Blood pressure machine (sphygmomanometer)	93.1 (87.8 – 98.5)	100	94.3 (89.9 – 98.7)	-	-	-
Delivery pack	85.1 (77.5 – 92.6)	100	87.6 (81.4 – 93.9)	-	-	-
Disposable gloves	100	100	100	-	-	-
Infection control in service area	88.5 (81.8 – 95.2)	100	90.5 (84.9 – 96.1)	-	-	-
Intravenous fluids and infusion set	93.1 (87.8 – 98.5)	100	94.3 (89.9 – 98.7)	-	-	-
Newborn resuscitation device	77.0 (68.1 – 85.9)	77.8 (58.5 – 78.6)	77.1 (66.5 – 87.8)	41.1	73.9	43.9
Suction apparatus	93.1 (87.8 – 98.5)	100	94.3 (89.9 – 98.7)	-	-	-
Uterotonic	96.6 (92.7 – 100)	100	97.1 (94.0 – 100)	51.2	82.6	53.9
ALL INPUTS AVAILABLE	18.4 (10.2 - 26.6)	55.6 (32.5 - 78.6)	24.8 (14.0 – 35.5)	17.7	21.7	18.1

The number of input measures it was possible to estimate in the DHIS2 was limited; no information was available on facility infrastructure and data was only captured on three of the 10 supply and commodity items included in the project-based estimate. Less than a fifth of facilities had all inputs available: 18% of PHCs and 22% of referral facilities. No items were universally available. The item most frequently available in PHCs was skilled birth attendant (73%) and uterotonic in referral (83%), while the item least frequently available in PHCs was anticonvulsant (34%) and in referral facilities skilled birth attendant (35%).

6.4.3 Step 3: Receipt of interventions

Over three-quarters of women were observed to receive all three interventions in the project data (see Table 6-5); ranging from 99% of women receiving a uterotonic to 87% of babies being weighed. Since the DHIS2 did not capture equivalent information, the second effective coverage measure took available data on receipt of interventions from the NDHS. In the NDHS 5% of women reported that they received all interventions; ranging from 75% of women receiving a uterotonic to 13% of babies being weighed.

Table 6-1-5 Receipt of intervention measures used in the summary variable that resulted in 'intervention-adjusted' coverage in the cascade

	Project observations of care	NDHS		
		PHC[1]	Referral[1]	All
Interventions				
Baby weighed	87.2 (73.2 – 100)	7.1 (2.7-11.5)	24.4 (13.2-35.5)	13.4 (8.0-18.8)
Prophylactic uterotonic	98.5 (97.1-99.9)	75.9 (67.8-84.0)	74.0 (66.1-81.9)	75.2 (69.9-80.5)
Thermal care	89.5 (81.8 – 97.1)	64.1 (56.7-71.5)	48.9 (36.9-60.9)	58.5 (52.8-64.2)
ALL INTERVENTIONS RECEIVED	**78.4 (64.0 – 92.8)**	**4.6 (1.1-8.0)**	**6.0 (1.9-10.0)**	**5.1 (2.5-7.6)**

TABLE NOTE: [1] NDHS coverage data calculated separately for women reporting attending a PHC or a referral facility for childbirth care

6.4.4 Step 4: Process of care

Process of care data was available in the project data but not the data typically available to decision makers (see Table 6-6). Overall, 24% of women were observed to receive all four processes of care. Across the three items undertaken by the birth attendant coverage ranged from 50% observed to take women's blood pressure to 70% observed explaining a procedure.

Table 6-1-6 Process of care measures used in the summary variable that resulted in 'quality-adjusted' coverage in the cascade

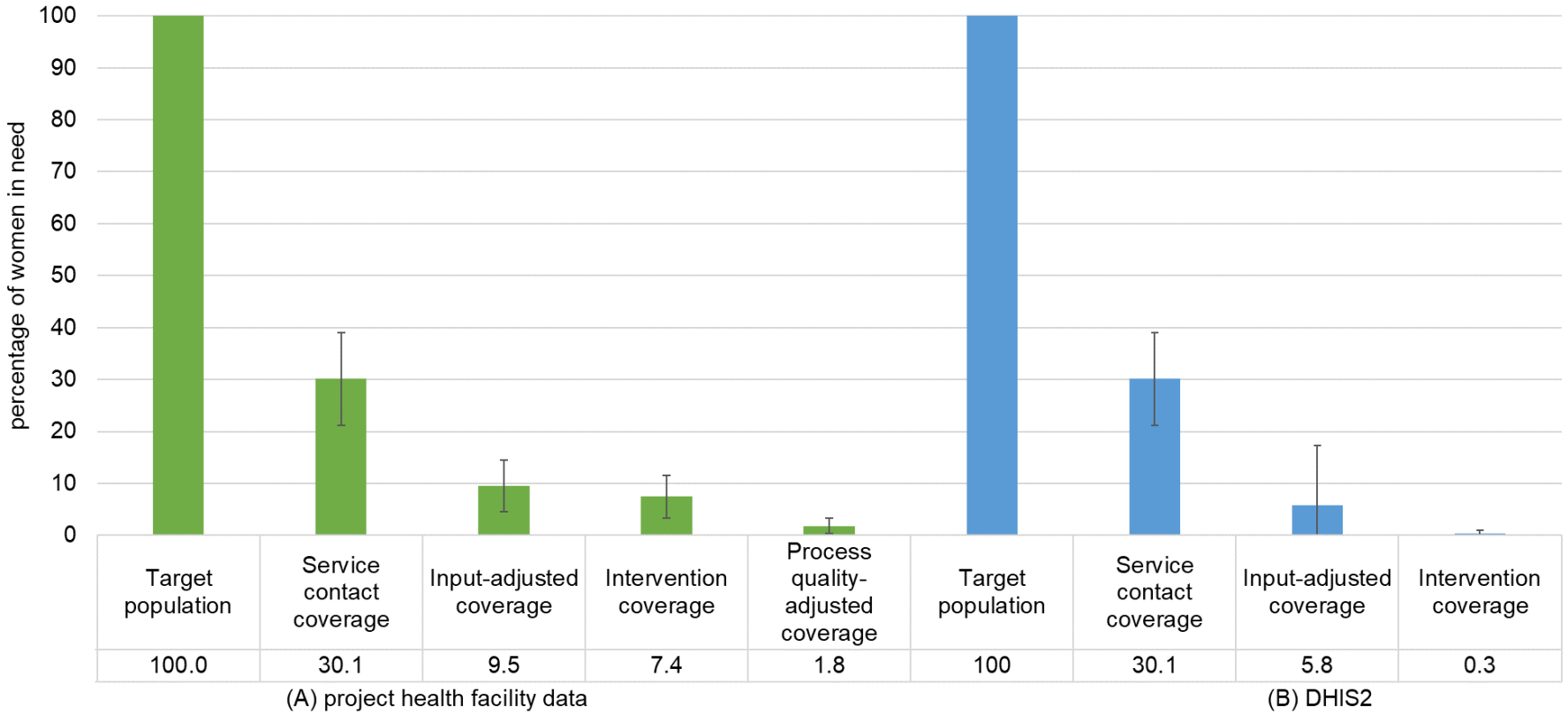
Process of care	Project observations of care
Takes woman's blood pressure	49.8 (31.3 – 68.2)
Explains procedure to woman or support person before proceeding	70.4 (63.4 – 77.3)
A support person (companion) for mother present at birth	54.3 (31.5 – 77.0)
Mother would recommend someone else to deliver in the facility	94.2 (88.5 – 99.9)
ALL PROCESSES OF CARE RECEIVED	**24.1** **(9.9 – 38.3)**

6.4.5 Effective coverage of facility based childbirth

Figure 6-1 presents the coverage cascade for facility based childbirth care in Gombe estimated using project data and datasets typically available to decision makers. NDHS was used in both estimates to estimate service contact (step 1). For the first effective coverage measure using the project data to calculate effective coverage from cascade steps 2 to 4, we observed that 2% of women in Gombe received high quality care during childbirth. The largest bottleneck was in access to a health facility; only 30% of women reported attending a health facility for childbirth. There was also a large reduction from service contact to input-adjusted coverage, with an attrition of 21%. The drop from input-adjusted coverage to intervention-adjusted coverage was relatively small, from 10% to 7%, reflecting the high percentage of women receiving all interventions.

For the second effective coverage measure using data typically available to decision makers in this setting we were able to calculate effective coverage up to cascade step 3. We observed that less than 0.5% of women were estimated to receive high quality care during childbirth. Again the largest bottleneck was in access to a health facility with only 30% of women attending a health facility for childbirth, and there was a large reduction from service contact to input-adjusted coverage, 30% to 6%.

Figure 1-1 Effective coverage of facility based childbirth in Gombe State, constructed using (a) NDHS and project facility data; and (b) NDHS and DHIS2



6.5 Discussion

Effective coverage measures are recommended as best practice for estimating population-level access to high quality maternal and newborn health care but there has been limited progress to operationalise measures. To maximise utility, there are increasing calls to make better use of routine data systems to generate estimates of effective coverage [7]. In this study, using different health facility data sources to estimate the effective coverage of facility based childbirth, we aimed to determine the feasibility of using data typically available to decision makers in this high mortality setting.

Our first approach linking NDHS to health facility survey data collected through a research project represents the most comprehensive health facility data available in this setting. It included a health facility survey and observations of birth, allowing linking of these different data sources with NDHS to calculate all four recommended cascade steps to estimate process quality-adjusted coverage of childbirth. The analysis revealed that less than 2% of women received effective coverage of childbirth care in Gombe state. Substantial gaps in the provision of high quality care were highlighted; coverage dropped from 30% of women who attended a facility for childbirth to 10% after accounting for the necessary inputs to provide high quality care during childbirth, dropping again to 7% after adjusting for intervention delivery and 2% after finally adjusting for processes of care. This finding adds to the wealth of evidence demonstrating large drops in coverage once some measurement of quality is accounted for [10].

In our second approach, only using data typically available to decision makers in this setting (NDHS and DHIS2) it was possible to measure three of the recommended steps in the cascade, up to intervention-adjusted coverage. This second approach resulted in lower adjusted coverage estimates at each step of the cascade. Differences in coverage estimates between the two combinations of data sources likely reflect differences in data collection methods and timeframes, with two particular areas of divergence. Regarding inputs, DHIS2 is a census of all facilities and availability of inputs was measured over the last six months, while the project health facility sample survey was conducted at one point in time and reflected availability on the day of survey. Regarding content of care, the second approach did not have the benefit of observations of care which might be considered the most reliable method to capture content of care during childbirth. Rather, it relied on NDHS data on women's reports about care received: this limited the number of items available for the adjustment, plus numerous studies have documented the poor validity of household survey data to assess receipt of interventions [34,45-47].

The results from both approaches highlight that facility readiness to provide care, the second cascade step and a crucial foundation to the provision of high quality of care [6], has not yet been met. Beyond this step the two approaches diverged. While a substantial drop in coverage was estimated from input-adjusted to intervention-adjusted coverage using data typically available in this setting (from 6% to 0.3%) this drop was relatively small in the project data (10% to 7%). And no adjustment for the fourth cascade step, processes of care, was possible using the second approach.

6.5.1 Strengths and limitations of the data typically available to decision makers

It is not appropriate for countries to routinely generate the comprehensive data that a focussed research project can collect. Nonetheless, there is clearly enormous potential to make better use of existing data sources for effective coverage measurement. Data on population need and care seeking is readily available from nationally representative population surveys, both DHS and MICS have been widely implemented in LMIC [48,49]. Importantly, these surveys are also designed to be representative at the State level, and as such are frequently used for benchmarking. However, local decision makers often seek more geographical granularity to inform actions; in Gombe state, for example, there is increasing interest to understand variation by LGA to be able to further examine inequalities in access and provision of high quality care across the State and support ongoing quality improvement initiatives. Further, local decision makers prefer more temporal estimates than retrospective household surveys like DHS or MICS can offer, although in this analysis we observed relative stability in access to care in the recent past. To facilitate analysis at lower levels requires alternative sources of population data and strengthening of administration data systems, for example civil registrations and vital statistics and a programme of household surveys to capture information on care seeking [50-52].

It was not possible to measure any components of the processes quality step in the data currently available to decision makers in this setting. Provision of care can be assessed in nationally representative surveys, such as SPA or SARA [26, 30]. However, neither currently include observations of childbirth as standard practice, require additional resources to do so, and are susceptible to the issue of temporality [53]. Unlike nationally representative surveys, DHIS2 is a census of all facilities and is available monthly, which offers opportunities to calculate effective coverage measures at the geographical level most useful to decision makers. Data on content of care is not currently present but could potentially be tracked in DHIS2. For example in Gombe State a number of relevant indicators are already captured at the facility level but are not included in the monthly monitoring reports to DHIS2 (see S1 Table) [34]. Extending HMIS so that data beyond inputs is routinely summarised for

managers to track depends on government priorities; this may require more advocacy to promote the need for including measures of the content of care.

6.5.2 Strength and limitations of the approach to measuring effective coverage

The effective coverage cascade is complex and needs further definition. The choice of items included in the effective coverage measure is likely to influence the estimate. Currently there is no standardised list of indicators for measuring quality of maternal and newborn health care [54-56], which poses a challenge to constructing effective coverage as noted by others [15]. Our approach to selecting items to measure each step was highly comprehensive based on a systematic review of the literature, WHO guidelines and cross-checked to ensure relevance to the local context. The measure constructed in the data typically available to decision makers was less comprehensive as not all data items were available (see Table 6-1), yet the key messages emerging from the analysis were similar.

Once the content of effective coverage measures has been defined (whether comprehensive or pragmatic, according to the data available), the methods for linking datasets for cascade analysis are becoming increasingly clear and accessible. We used validated ecological linking approaches, accounting for facility type, to combine datasets [13,14,42], and variance was estimated using the recommended delta method [43].

6.6 Conclusions

Comprehensive project data revealed that effective coverage of childbirth care in Gombe state is low and more attention is needed on this problem. This study also demonstrates that it is already feasible to partially construct effective coverage measures using routine data from HMIS combined with national level population survey sources. Advocacy to include process of care indicators in facility summary reports could optimise this data source for local decision making and take us a step closer to operationalising effective coverage measurement at the country level.

Acknowledgements:

The authors would like to thank Data Research and Mapping Consult for coordinating the IDEAS project data collection, the Gombe State Primary Health Care Development Agency (GSPHCDA), Gombe State Ministry of Health and our partners Society for Family Health and Pact Nigeria for their support in carrying out this study. In particularly we would like to thank Christopher Istakis from the GSPHCDA for his support in accessing DHIS2. Finally, we would like to thank all the participants who contributed to our study.

6.7 References

1. Bhutta ZA, Das JK, Bahl R, Lawn JE, Salam RA, Paul VK, et al. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? Lancet (London, England). 2014;384(9940):347-70. Epub 2014/05/24. doi: 10.1016/s0140-6736(14)60792-3. PubMed PMID: 24853604.
2. Chou VB, Walker N, Kanyangarara M. Estimating the global impact of poor quality of care on maternal and neonatal outcomes in 81 low- and middle-income countries: A modeling study. PLoS Med. 2019;16(12):e1002990. Epub 2019/12/19. doi: 10.1371/journal.pmed.1002990. PubMed PMID: 31851685.
3. Kruk ME, Gage AD, Joseph NT, Danaei G, Garcia-Saiso S, Salomon JA. Mortality due to low-quality health systems in the universal health coverage era: a systematic analysis of amenable deaths in 137 countries. Lancet (London, England). 2018;392(10160):2203-12. Epub 2018/09/10. doi: 10.1016/s0140-6736(18)31668-4. PubMed PMID: 30195398.
4. Requejo JH, Bryce J, Barros AJ, Berman P, Bhutta Z, Chopra M, et al. Countdown to 2015 and beyond: fulfilling the health agenda for women and children. Lancet (London, England). 2015;385(9966):466-76. Epub 2014/07/06. doi: 10.1016/s0140-6736(14)60925-9. PubMed PMID: 24990815.
5. Tunçalp Ö, Were W, MacLennan C, Oladapo O, Gülmezoglu A, Bahl R, et al. Quality of care for pregnant women and newborns—the WHO vision. Bjog. 2015;122(8):1045-9. doi: 10.1111/1471-0528.13451.
6. Kruk ME, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-DeWan S, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. The Lancet Global health. 2018.
7. Marsh AD, Muzigaba M, Diaz T, Requejo J, Jackson D, Chou D, et al. Effective coverage measurement in maternal, newborn, child, and adolescent health and nutrition: progress, future prospects, and implications for quality health systems. The Lancet Global health. 2020;8(5):e730-e6. doi: 10.1016/S2214-109X(20)30104-2.
8. Murray CJL, Evans DB. Technical Consultation on Effective Coverage in Health Systems. Health systems performance assessment : debates, methods and empiricism. Geneva: World Health Organization; 2003. p. 125-34.
9. Ng M, Fullman N, Dieleman JL, Flaxman AD, Murray CJL, Lim SS. Effective Coverage: A Metric for Monitoring Universal Health Coverage. PLoS Med. 2014;11(9):e1001730. doi: 10.1371/journal.pmed.1001730.
10. Amouzou A, Leslie HH, Ram M, Fox M, Jiwani SS, Requejo J, et al. Advances in the measurement of coverage for RMNCH and nutrition: from contact to effective coverage. BMJ Glob Health. 2019;4(Suppl 4):e001297. doi: 10.1136/bmjgh-2018-001297.
11. Do M, Micah A, Brondi L, Campbell H, Marchant T, Eisele T, et al. Linking household and facility data for better coverage measures in reproductive, maternal, newborn, and child health care: systematic review. Journal of global health. 2016;6(2):020501. Epub 2016/09/09. doi: 10.7189/jogh.06.020501. PubMed PMID: 27606060.
12. Kanyangarara M, Chou VB, Creanga AA, Walker N. Linking household and health facility surveys to assess obstetric service availability, readiness and coverage: evidence from 17 low- and middle-income countries. Journal of global health. 2018;8(1):010603. Epub 2018/06/05. doi: 10.7189/jogh.08.010603. PubMed PMID: 29862026.
13. Munos MK, Maiga A, Do M, Sika GL, Carter ED, Mosso R, et al. Linking household survey and health facility data for effective coverage measures: a comparison of ecological and individual linking methods using the Multiple Indicator Cluster Survey in Côte d'Ivoire. Journal of global health. 2018;8(2):020803. Epub 2018/11/10. doi: 10.7189/jogh.08.020803. PubMed PMID: 30410743.
14. Willey B, Waiswa P, Kajjo D, Munos M, Akuze J, Allen E, et al. Linking data sources for measurement of effective coverage in maternal and newborn health: what do we learn from individual- vs ecological-linking methods? Journal of global health. 2018;8(1):010601. Epub 2018/03/03. doi: 10.7189/jogh.08.010601. PubMed PMID: 29497508.

15. Exley J, Gupta PA, Schellenberg J, Strong K, Requejo J, Moller AB, et al. A rapid systematic review and evidence synthesis of effective coverage measures and cascades for childbirth, newborn and child health in low- and middle-income countries. Journal of global health. 2021;12. Epub 15 January 2022.
16. Leslie HH, Doubova SV, Pérez-Cuevas R. Assessing health system performance: effective coverage at the Mexican Institute of Social Security. Health policy and planning. 2019;34(Supplement_2):ii67-ii76. Epub 2019/11/15. doi: 10.1093/heapol/czz105. PubMed PMID: 31723962.
17. Gombe State Government [Internet]. History of Gombe State, Nigeria. [cited 9 Sept 2021]. Available from: http://gombestate.gov.ng/history-2/.
18. National Bureau of Statistics (NBS) and United Nations Children's Fund (UNICEF). Multiple Indicator Cluster Survey 2016-17, Survey Findings Report. Abuja, Nigeria: National Bureau of Statistics and United Nations Children's Fund. 2017.
19. Izugbara CO, Wekesah FM, Adedini SA. Maternal Health in Nigeria. A Situation Update. Nairobi, Kenya: African Population and Health Research Centre, 2016.
20. Bhattacharya AA, Umar N, Audu A, Felix H, Allen E, Schellenberg JRM, et al. Quality of routine facility data for monitoring priority maternal and newborn indicators in DHIS2: A case study from Gombe State, Nigeria. PloS one. 2019;14(1):e0211265. Epub 2019/01/27. doi: 10.1371/journal.pone.0211265. PubMed PMID: 30682130.
21. IDEAS team. Informed Decisions for Actions in Maternal and Newborn Health 2010-17 Report: What works, why and how in maternal and newborn health [Internet]. IDEAS, London School of Hygiene & Tropical Medicine: 2017 [cited 9 Sept 2021]. Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/09/LSHTM_IDEAS_PhaseIReport_Web-reduced.pdf
22. Makowiecka K, Marchant T, Betemariam W, Chaturvedi A, Jana L, Liman A, et al. Characterising innovations in maternal and newborn health based on a common theory of change: lessons from developing and applying a characterisation framework in Nigeria, Ethiopia and India. BMJ Glob Health. 2019;4(4):e001405. Epub 2019/08/14. doi: 10.1136/bmjgh-2019-001405. PubMed PMID: 31406587.
23. Makowiecka K. The Pathway to Improved Maternal and Newborn Health Outcomes. Use of data for maternal and newborn health in Gombe State, Nigeria [Internet]. IDEAS, London School of Hygiene & Tropical Medicine: 2016 [cited 9 Sept 2021]. Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/08/Makowiecka_IDEAS_Pathway_Improved_Maternal_Newborn_Health_Gombe_Nigeria_2016.pdf
24. Willey B, Umar N, Beaumont E, Allen E, Anyanti J, Bello AB, et al. Improving maternal and newborn health services in Northeast Nigeria through a government-led partnership of stakeholders: a quasi-experimental study. BMJ Open. 2022;12(2):e048877. doi: 10.1136/bmjopen-2021-048877.
25. Bhattacharya AA, Allen E, Umar N, Audu A, Felix H, Schellenberg J, et al. Improving the quality of routine maternal and newborn data captured in primary health facilities in Gombe State, Northeastern Nigeria: a before-and-after study. BMJ Open. 2020;10(12):e038174. doi: 10.1136/bmjopen-2020-038174.
26. Joseph NT, Piwoz E, Lee D, Malata A, Leslie HH. Examining coverage, content, and impact of maternal nutrition interventions: the case for quality-adjusted coverage measurement. Journal of global health. 2020;10(1):010501. Epub 2020/02/23. doi: 10.7189/jogh.10.010501. PubMed PMID: 32082545.
27. Kemp CG, Sorensen R, Puttkammer N, Grand'Pierre R, Honoré JG, Lipira L, et al. Health facility readiness and facility-based birth in Haiti: a maximum likelihood approach to linking household and facility data. Journal of global health reports. 2018;2:e2018023. Epub 2018/01/01. doi: 10.29392/joghr.2.e2018023. PubMed PMID: 31406933.
28. Nguhiu PK, Barasa EW, Chuma J. Determining the effective coverage of maternal and child health services in Kenya, using demographic and health survey data sets: tracking progress towards universal health coverage. Tropical medicine & international health : TM &

IH. 2017;22(4):442-53. Epub 2017/01/18. doi: 10.1111/tmi.12841. PubMed PMID: 28094465.
29. Nguyen PH, Khương LQ, Pramanik P, Billah SM, Menon P, Piwoz E, et al. Effective coverage of nutrition interventions across the continuum of care in Bangladesh: insights from nationwide cross-sectional household and health facility surveys. BMJ Open. 2021;11(1):e040109. Epub 2021/01/22. doi: 10.1136/bmjopen-2020-040109. PubMed PMID: 33472778.
30. Sharma J, Leslie HH, Kundu F, Kruk ME. Poor Quality for Poor Women? Inequities in the Quality of Antenatal and Delivery Care in Kenya. PloS one. 2017;12(1):e0171236. Epub 2017/02/01. doi: 10.1371/journal.pone.0171236. PubMed PMID: 28141840.
31. Wang W, Mallick L, Allen C, Pullum T. Effective coverage of facility delivery in Bangladesh, Haiti, Malawi, Nepal, Senegal, and Tanzania. PloS one. 2019;14(6):e0217853. Epub 2019/06/12. doi: 10.1371/journal.pone.0217853. PubMed PMID: 31185020.
32. National Population Commission - NPC, ICF. Nigeria Demographic and Health Survey 2018 - Final Report. Abuja, Nigeria: NPC and ICF, 2019.
33. Marchant T. Change in maternal and newborn health care. Interactions between families and frontline workers - their frequency, quality and equity - and coverage of interventions of mothers and newborns. Report from Gombe State, Nigeria, 2012-2015 [Internet]. IDEAS, London School of Hygiene & Tropical Medicine: 2016 [cited 9 Sept 2021]. Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/08/Marchant_IDEAS_Gombe_State_Follow-upSurvey_2016.pdf.
34. Bhattacharya AA, Allen E, Umar N, Usman AU, Felix H, Audu A, et al. Monitoring childbirth care in primary health facilities: a validity study in Gombe State, northeastern Nigeria. Journal of global health. 2019;9(2):020411. Epub 2019/07/31. doi: 10.7189/jogh.09.020411. PubMed PMID: 31360449.
35. Exley J, Hanson C, Umar N, Willey B, Shuaibu A, Marchant T. Provision of essential evidence-based interventions during facility-based childbirth: cross-sectional observations of births in northeast Nigeria. BMJ Open. 2020;10(10):e037625. Epub 2020/10/26. doi: 10.1136/bmjopen-2020-037625. PubMed PMID: 33099494.
36. USAID & MCHIP [Internet]. Washington; Maternal and Child Health Integrated Program. Maternal and Newborn Quality of Care Surveys. [cited 14 Oct 2021]. Available from: https://www.mchip.net/qocsurveys/
37. DHIS2 [Internet]. University of Oslo; HISP Centre. About DHIS2 [cited11 Oct 2021]. Available from: https://dhis2.org/about/
38. WHO. Standards for improving quality of maternal and newborn care in health facilities. World Health Organization: Geneva. 2016.
39. World Health Organization. WHO recommendations: intrapartum care for a positive childbirth experience. Geneva: World Health Organization, 2018.
40. World Health Organization. Consultation on improving measurement of the quality of maternal, newborn and child care in health facilities. Geneva: World Health Organization, 2013.
41. World Health Organization, United Nations Population Fund, UNICEF. Pregnancy, childbirth, postpartum and newborn care. A guide for essential practice (3rd edition). Geneva: World Health Organization, 2015.
42. Carter ED, Ndhlovu M, Eisele TP, Nkhama E, Katz J, Munos M. Evaluation of methods for linking household and health care provider data to estimate effective coverage of management of child illness: results of a pilot study in Southern Province, Zambia. Journal of global health. 2018;8(1):010607. Epub 2018/07/10. doi: 10.7189/jogh.08.010607. PubMed PMID: 29983929.
43. Sauer SM, Pullum T, Wang W, Mallick L, Leslie HH. Variance estimation for effective coverage measures: A simulation study. Journal of global health. 2020;10(1):010506. Epub 2020/04/08. doi: 10.7189/jogh-10-010506. PubMed PMID: 32257160.
44. Baker U, Peterson S, Marchant T, Mbaruku G, Temu S, Manzi F, et al. Identifying implementation bottlenecks for maternal and newborn health interventions in rural districts of

the United Republic of Tanzania. Bulletin of the World Health Organization. 2015;93(6):380-9. Epub 2015/08/05. doi: 10.2471/blt.14.141879. PubMed PMID: 26240459.
45. Blanc AK, Warren C, McCarthy KJ, Kimani J, Ndwiga C, RamaRao S. Assessing the validity of indicators of the quality of maternal and newborn health care in Kenya. Journal of global health. 2016;6(1):010405. Epub 2016/05/28. doi: 10.7189/jogh.06.010405. PubMed PMID: 27231541.
46. McCarthy KJ, Blanc AK, Warren CE, Kimani J, Mdawida B, Ndwidga C. Can surveys of women accurately track indicators of maternal and newborn care? A validity and reliability study in Kenya. Journal of global health. 2016;6(2):020502. Epub 2016/09/09. doi: 10.7189/jogh.06.020502. PubMed PMID: 27606061.
47. Stanton CK, Rawlins B, Drake M, Dos Anjos M, Cantor D, Chongo L, et al. Measuring coverage in MNCH: testing the validity of women's self-report of key maternal and newborn health interventions during the peripartum period in Mozambique. PloS one. 2013;8(5):e60694. Epub 2013/05/15. doi: 10.1371/journal.pone.0060694. PubMed PMID: 23667427.
48. The Demographic and Health Surveys Program [Internet]. Rockville; USAID. The DHS Program: Country List. [cited 11 Oct 2021]. Available from: https://www.dhsprogram.com/Countries/Country-List.cfm
49. UNICEF [Internet]. About MICS. [cited 14 Oct 2021]. Available from: https://mics.unicef.org/about
50. AbouZahr C, Boerma T. Health information systems: the foundations of public health. Bulletin of the World Health Organization. 2005;83(8):578-83. Epub 2005/09/27. PubMed PMID: 16184276.
51. United Nations Statistics Division [Internet]. New York: United Nations. Demographic and Social Statistics: Civil Registration and Vital Statistics. [cited 14 Oct 2021]. Available from: https://unstats.un.org/unsd/demographic-social/crvs/
52. Yokobori Y, Obara H, Sugiura Y, Kitamura T. Gaps in the civil registration and vital statistics systems of low- and middle-income countries and the health sector's role in improving the situation. Glob Health Med. 2021;3(4):243-5. doi: 10.35772/ghm.2020.01103. PubMed PMID: 34532606.
53. Sheffel A, Karp C, Creanga AA. Use of Service Provision Assessments and Service Availability and Readiness Assessments for monitoring quality of maternal and newborn health services in low-income and middle-income countries. BMJ Glob Health. 2018;3(6):e001011. Epub 2018/12/18. doi: 10.1136/bmjgh-2018-001011. PubMed PMID: 30555726.
54. Marchant T, Bryce J, Victora C, Moran AC, Claeson M, Requejo J, et al. Improved measurement for mothers, newborns and children in the era of the Sustainable Development Goals. Journal of global health. 2016;6(1):010506. Epub 2016/07/16. doi: 10.7189/jogh.06.010506. PubMed PMID: 27418960.
55. Moller A-B, Newby H, Hanson C, Morgan A, El Arifeen S, Chou D, et al. Measures matter: A scoping review of maternal and newborn indicators. PloS one. 2018;13(10):e0204763. doi: 10.1371/journal.pone.0204763.
56. Moxon SG, Ruysen H, Kerber KJ, Amouzou A, Fournier S, Grove J, et al. Count every newborn; a measurement improvement roadmap for coverage data. BMC Pregnancy Childbirth. 2015;15 Suppl 2:S8. Epub 2015/09/24. doi: 10.1186/1471-2393-15-s2-s8. PubMed PMID: 26391444.

7 Objective 4: assessing inequalities in effective coverage

To assess inequalities in effective coverage I undertook an exploratory analysis and wrote a commentary highlighting the methodological constraints associated with the existing data sources most commonly used to construct effective coverage measures that limit our ability to examine inequalities. The commentary was published in BMJ Global Health

*Exley, J. and T. Marchant (2022). "Inequalities in effective coverage measures: are we asking too much of the data?" BMJ Global Health **7**(5): e009200.*

The exploratory analysis and the commentary are presented in the rest of this chapter.

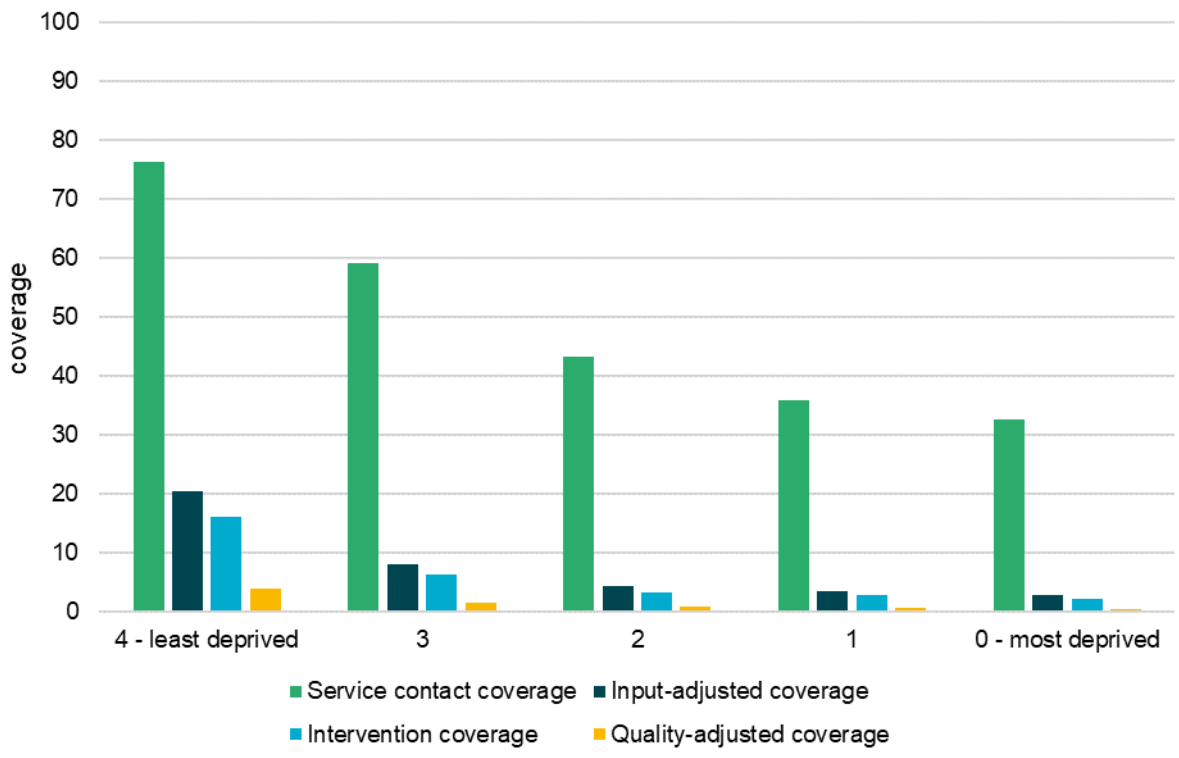
7.1 Exploratory analysis of inequalities in effective coverage of childbirth care

High quality childbirth care should be available to all women; it is therefore a priority that effective coverage measures be disaggregated by key determinants of inequalities to redress existing inequities (5, 28, 62). Using project data, I undertook an exploratory analysis of inequalities in effective coverage of childbirth care in Gombe, by SES.

Effective coverage of facility based childbirth by SES is presented in Figure 7-1. It can be seen that the least deprived women were more likely to seek childbirth care at a facility (76.4% in least deprived vs. 32.7% in most deprived) and more likely to receive high quality of care: process-quality adjusted coverage 3.9% in least deprived vs. 0.5% in most deprived. However, the relative difference in coverage between SES groups is the same for each step of the cascade from input-adjusted coverage onwards; suggesting that differences observed between groups is being driven by differences in care-seeking.

The project facility data is summarised at the facility level and not available at the individual-level. As such, women are assigned the average quality score and it is not possible to examine difference in the quality of care that women from different SES groups might experience within a facility.

Figure 7-1 Effective coverage of facility based childbirth in Gombe State by socioeconomic status, constructed using project data



Inequalities in effective coverage measures: are we asking too much of the data?

Josephine Exley MSc[1] and Tanya Marchant PhD[1]

Authors affiliations

1 Department of Disease Control, London School of Hygiene & Tropical Medicine, London, WC1E 7HT, UK

Correspondence to Josephine Exley (Josephine.Exley@lshtm.ac.uk; Department of Disease Control, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT, United Kingdom)

Summary box:

- The need to shift to effective coverage measures has gained widespread acknowledgment. Effective coverage combines need, use and quality of care into a single metric to estimate the proportion of a population in need of a service that resulted in a positive health outcome from that service.
- To support efforts towards universal health coverage, effective coverage measures should assess inequalities. At present direct measures of equity, such as wealth, age, ethnicity, gender, education, place of residence, are only available in household data. However, population-level data alone does not provide information on all components of quality of care and may have poor validity.
- Many measure of effective coverage require linking household data with information from health facilities on the quality of care provided. Health facility data provides a summary of quality of care at the facility-level, and consequently ignores variation that may exist between service users with different characteristics.
- Inequalities in effective coverage may be larger than we are able to demonstrate using existing data sources most commonly used to construct effective coverage measures

Effective coverage measures combine need, use and quality of care into a single metric to estimate the benefit of a service or intervention. Effective coverage is defined as the proportion of the population in need of a service that resulted in a positive health outcome from that service.[1] For reproductive, maternal, newborn, child health and nutrition (RMNCH+N) services and interventions, effective coverage can be defined using a cascade (see Figure 7-2). Effective coverage is represented by the final step of the cascade, while the full cascade can be used to identify bottlenecks in implementation.

Universal health coverage means that high quality interventions and services are available to all.[2-4] Inequalities in the availability and quality of health services exist at all levels: between geographic regions, within geographic regions, and even within individual health facilities and families.[5] To address inequalities effective coverage measures should be disaggregated by key socio-demographic and economic variables[1] - such as wealth, age, ethnicity, gender, education, place of residence.[6]

The potential to investigate inequalities in effective coverage is dependent on the data used to construct each step in the cascade. Here, we illustrate two methodological constraints that limit measuring inequalities in effective coverage when using: 1) only population-based data such as DHS or MICS (for example complementary feeding interventions); and 2) linked population and health facility data such as SPA or SARA (for example high quality childbirth care), summarised in Figure 7-2.

1. **Population-level data alone does not provide information on all quality of care steps of the cascade and may have low validity.**

A literature review of effective coverage measures revealed 14 studies that used only population level data.[7] A common example was treatment for malnutrition that typically reflected caregiver reports of whether nutritional interventions were received, whether children were ever given nutritional interventions, and whether the interventions were used appropriately in the household (see Figure 7-2). Quality dimensions of health provider practise were not incorporated.

Since information on socio-demographic and economic variables are typically captured in household surveys it is possible to stratify each of the relevant steps of the cascade by the desired measure of equity. However, household data provides no information on inputs and evidence on the validity of coverage data collected through household surveys suggests that while it can provide accurate coverage measures for some interventions, for many interventions household respondents cannot accurately report on quality of care dimensions.[8-10] For the latter, alternative measurement approaches that link multiple data sources have been recommended.

2. Facility-level data does not include the individual data needed to track inequalities.

For many services (such as childbirth care) effective coverage measurement relies on linking data on access to care, derived from household surveys, where measures of inequality are incorporated, with information on the quality of care (inputs, interventions, process and experience of care) from health facility datasets.[11-13] Health facility data e.g. nationally representative surveys such as SPA or SARA or indeed routine data sources such as DHIS-2, do not report individual-level data but instead provide a summary of a facility's capacity to provide high quality care. Applying a facility-level score to each step of the cascade derived from health data (see Figure 7-2), assumes that there are no systematic differences in the quality of care between individuals attending the same facility. However, evidence demonstrates that this is not the case; individuals with different characteristics receive different quality of care.[5 14] Estimates of inequalities in effective coverage measures that are derived from linked household and facility data are driven only by the access to care measure.

There are further implications depending on the method applied for linking household and health facility data, whether: 1) individual or exact-match linking or 2) ecological linking.[11-13]

Exact-match linking of individuals in population data to the exact health facility they attended will capture systematic differences in care seeking behaviour between individuals with different characteristics – for example that wealthier individuals are more likely to bypass their nearest sources of care to seek higher quality care - either outside of their catchment area or at a higher-level facility.[5 15] Ecological linking - in which individuals from population data sources are linked to an average quality score across multiple health facilities - takes us a step further away, since it assumes there are no systematic differences in care seeking behaviour between individuals with different characteristics. Adjusting for the type of facility that people report receiving care from has been demonstrated to generate valid measures of effective coverage, as likely accounts for some difference in care seeking behaviour.[12 13] Even so the approach ignores intersectionality and assumes that the quality and experience of care is homogeneous across facilities included in the average score i.e. that the average quality of primary health care facilities accessed by the wealthiest people is the same as the average quality score for primary health care facilities accessed by the poorest people.

Herein lies the measurement dilemma. Relying on summary facility measures for linked effective coverage ignores variation in quality of care both within and (where using ecological linking approaches) between facilities. While generating effective coverage measures using only household data limits the adjustment made for quality and introduces issues with the reliability and validity of measures. In both scenarios, inequalities in effective coverage are

driven only by the steps that access population data and are likely to be underestimated as a result. It is important to be mindful of which stratified analyses are feasible and what they are able to tell us about inequalities in effective coverage; and refrain from asking too much of the data.

Effective coverage measures remain a crucial tool as we move towards universal access to high quality care; we need to adjust coverage measures for the process and experience of care for individuals. Alongside continuing to promote effective coverage we need to support the adoption of unique health identifiers that would allow us to link information on individuals' care seeking with information on the quality of care received. In the meantime, greater advocacy and investment in health information systems is needed to shift from reporting aggregated- to individual-level data and to capture information on individual patients that would enable examination of inequalities within facilities.

Figure 7-2 Overview of the data used to measure each step of the coverage cascade* and the stratification possible for complementary food product and childbirth care

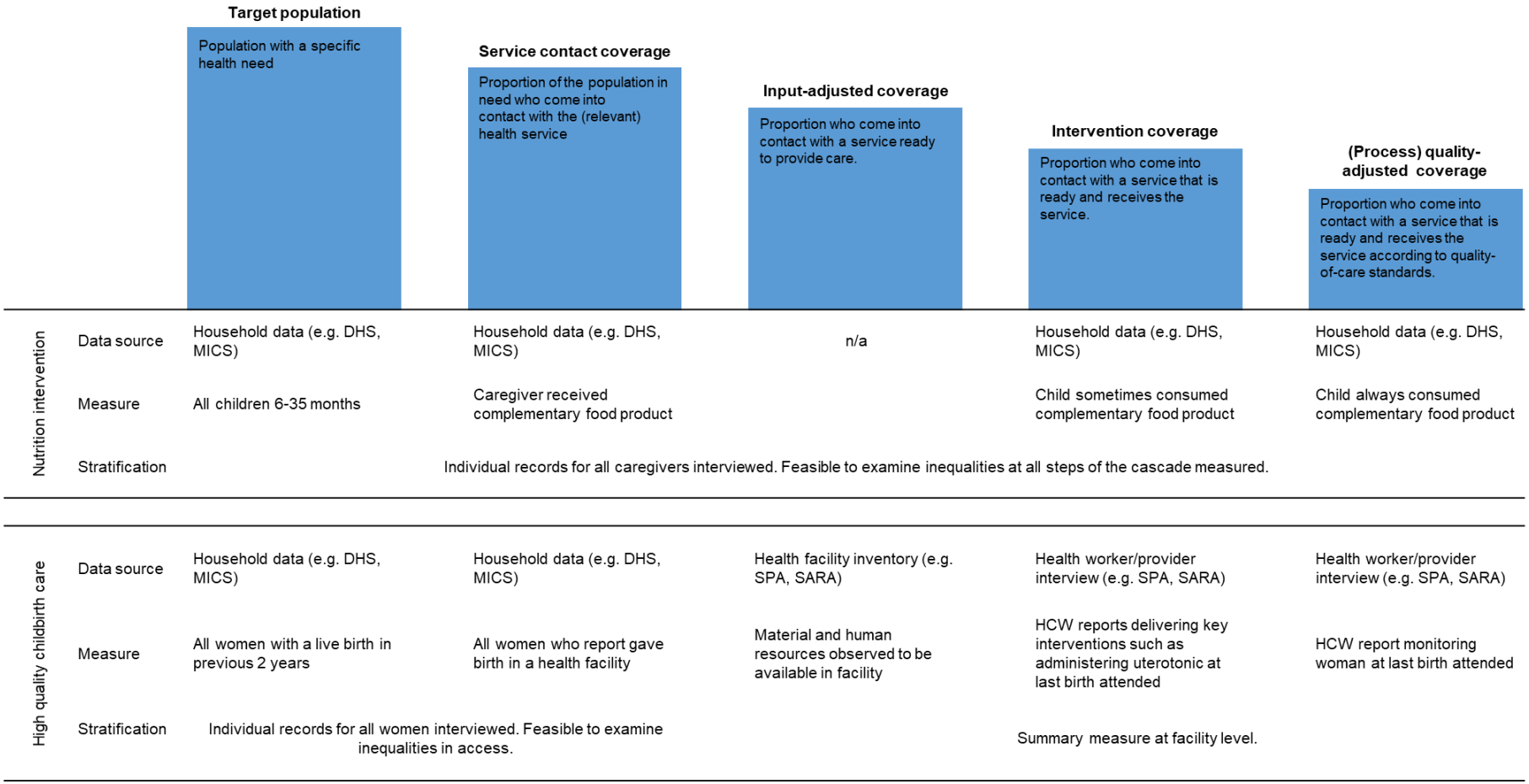


FIGURE NOTE * adapted from Marsh et al. 2020[1]

Contributors:

JE and TM conceptualised the commentary. JE wrote the initial draft, and TM reviewed and edited the manuscript.

Competing interests:

The authors declare no competing interests.

Funding:

JE and TM work on the IDEAS (Informed Decisions for Actions to improve maternal and newborn health) project, funded through a grant from the Bill & Melinda Gates Foundation to the London School of Hygiene & Tropical Medicine. Gates Global Health Grant Number: OPP1149259/INV-007644. The funder played no role in the conceptualisation, the decision to publish or preparation of the commentary.

Acknowledgments:

We would like to thank Joanna Schellenberg (LSHTM) and James Hargreaves (LSHTM) for their review of an earlier draft of this commentary.

7.2 References

1. Marsh AD, Muzigaba M, Diaz T, et al. Effective coverage measurement in maternal, newborn, child, and adolescent health and nutrition: progress, future prospects, and implications for quality health systems. *The Lancet Global health* 2020;8(5):e730-e36. doi: 10.1016/S2214-109X(20)30104-2
2. Kruk ME, Gage AD, Arsenault C, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. *The Lancet Global health* 2018
3. Requejo J, Diaz T, Park L, et al. Assessing coverage of interventions for reproductive, maternal, newborn, child, and adolescent health and nutrition. *BMJ* 2020;368:l6915. doi: 10.1136/bmj.l6915
4. World Health Organization. Inequality monitoring in sexual, reproductive, maternal, newborn, child and adolescent health: a step-by-step manual. Geneva: World Health Organization 2022:x, 82 p.
5. Fink G, Kandpal E, Shapira G. Inequality in the Quality of Health Services: Wealth, Content of Care, and Price of Antenatal Consultations in the Democratic Republic of Congo. *Policy Research Working Papers* 2019;No 8818(World Bank, Washington, DC) doi: https://doi.org/10.1596/1813-9450-8818
6. Barros AJ, Victora CG. Measuring coverage in MNCH: determining and interpreting inequalities in coverage of maternal, newborn, and child health interventions. *PLoS Med* 2013;10(5):e1001390. doi: 10.1371/journal.pmed.1001390 [published Online First: 2013/05/15]
7. Exley J, Gupta PA, Schellenberg J, et al. A rapid systematic review and evidence synthesis of effective coverage measures and cascades for childbirth, newborn and child health in low- and middle-income countries. *Journal of global health* 2021;12 [published Online First: 15 January 2022]
8. Munos MK, Stanton CK, Bryce J. Improving coverage measurement for reproductive, maternal, neonatal and child health: gaps and opportunities. *Journal of global health* 2017;7(1):010801. doi: 10.7189/jogh.07.010801 [published Online First: 2017/06/14]
9. Bhattacharya AA, Allen E, Umar N, et al. Monitoring childbirth care in primary health facilities: a validity study in Gombe State, northeastern Nigeria. *Journal of global health* 2019;9(2):020411. doi: 10.7189/jogh.09.020411 [published Online First: 2019/07/31]
10. Carter ED, Ndhlovu M, Munos M, et al. Validity of maternal report of care-seeking for childhood illness. *Journal of global health* 2018;8(1):010602. doi: 10.7189/jogh.08.010602 [published Online First: 2018/04/06]
11. Do M, Micah A, Brondi L, et al. Linking household and facility data for better coverage measures in reproductive, maternal, newborn, and child health care: systematic review. *Journal of global health* 2016;6(2):020501. doi: 10.7189/jogh.06.020501 [published Online First: 2016/09/09]
12. Munos MK, Maiga A, Do M, et al. Linking household survey and health facility data for effective coverage measures: a comparison of ecological and individual linking methods using the Multiple Indicator Cluster Survey in Côte d'Ivoire. *Journal of global health* 2018;8(2):020803. doi: 10.7189/jogh.08.020803 [published Online First: 2018/11/10]
13. Willey B, Waiswa P, Kajjo D, et al. Linking data sources for measurement of effective coverage in maternal and newborn health: what do we learn from individual- vs ecological-linking methods? *Journal of global health* 2018;8(1):010601. doi: 10.7189/jogh.08.010601 [published Online First: 2018/03/03]
14. Sharma J, Leslie HH, Kundu F, et al. Poor Quality for Poor Women? Inequities in the Quality of Antenatal and Delivery Care in Kenya. *PloS one* 2017;12(1):e0171236. doi: 10.1371/journal.pone.0171236 [published Online First: 2017/02/01]
15. Mubiri P, Kajjo D, Okuga M, et al. Bypassing or successful referral? A population-based study of reasons why women travel far for childbirth in Eastern Uganda. *BMC Pregnancy and Childbirth* 2020;20(1):497. doi: 10.1186/s12884-020-03194-2

Discussion & conclusions

8 Discussion

Effective coverage has emerged as a key indicator for monitoring progress towards universal health coverage, and within MNCAHN it is now recommended that effective coverage be defined using health-service coverage cascades applied at the population level (28). Despite endorsement at the global level, there are few examples of effective coverage having been adopted at the country level and gaps remain in operationalising the MNCAHN effective care cascade framework. Building directly on the work of the Effective Coverage Think Tank Group, this PhD aimed to contribute to the advancement of effective coverage measures by operationalising the coverage cascades for childbirth care, using data from Gombe State in northeast Nigeria.

Generating measures of effective coverage of childbirth requires linking data on access to care, derived from household surveys with information on the quality of care (inputs, interventions, process and experience of care) from health facility datasets (45, 51, 53, 59, 60). This PhD demonstrates that the effective coverage cascade of childbirth care can be constructed linking household data to health facility survey data and that it is feasible to partially construct a cascade using health facility data sources routinely available to decision makers in low resource settings, such as Gombe. Overall, effective coverage was found to be low in this setting and points to critical gaps in the availability of inputs and commodities needed to provide high quality care and poor implementation of process-quality.

The findings add to calls for a need to build global consensus for greater harmonisation on standard indicators and guidance on best practice for constructing effective coverage measures, including how to define the content and the data sources for each step of the cascade. They also identify the need for action to broaden the scope of existing data sources to capture process-quality indicators and increased attention to the measurement of inequalities in effective coverage to ensure high quality health services for all.

In the rest of this discussion section, I will briefly summarise the key findings for each of the research objectives in turn, reflect on the key limitations of the approach taken before going on to consider the implications for quality of childbirth care in Gombe and effective coverage measurement of childbirth care. Finally, I will briefly reflect on the implications for effective coverage more broadly and make some recommendations on areas for further research.

8.1 Summary of findings

8.1.1 Objective 1: analysis of observations of childbirth care

The analysis of observation of childbirth in ten PHCs in Gombe found that the proportion of women and their newborns who consistently received evidence based care was low. There was substantial variation in implementation of evidence-based interventions both within and across the different stages of childbirth care; clinical interventions delivered around the time of birth that have received international attention (26), such as administering a uterotonic, thermal and clean cord care, were found to be routinely well implemented (coverage ≥80%), whilst interventions related to risk assessment, such as history-taking and checking vital signs, were poorly implemented (coverage <30%).

8.1.2 Objective 2: systematic review of the content of effective coverage measures

The systematic review revealed substantial heterogeneity in both definitions and construction of existing effective coverage measures of childbirth care, limiting the comparability of these measures over time and across settings. The results demonstrate that the cascade represents a considerable shift in approach to measuring effective coverage; only two of the 17 childbirth care studies captured indicators related to all steps of the cascade in a single measure (52, 55). The majority of measures adjusted contact coverage for only one component of quality of care - most commonly inputs, measured using health facility assessment data. Indicators related to the intervention and process-quality steps of the cascade were measured using a number of different data sources, including healthcare workers' reports of their actions taken in health facility assessments, health facility records, women's self-reports in household survey data and direct observations of childbirth care from SPA. Further, there was little consistency in the number or type of indicators used to define quality of care nor in the methods for generating a summary score; a notable gap was the lack of indicators related to patient experience of care – captured by only two studies (49, 52).

The differences in approach between studies is likely a reflection of the wider challenges of measuring quality of care, given the lack of standardised indicators (9, 23, 34, 35), and is likely to be driven by the focus of the study and data availability (21, 108). However, even where studies had relevant data available, they did not always adjust for all components of quality of care as proposed in the cascade. For example, Joseph et al. used the 2013-14 Malawi SPA data - which was expanded beyond the standard protocol to include direct observations of normal obstetric delivery and immediate newborn care - to adjust contact coverage for indicators related to interventions and process-quality steps of the cascade but did not adjust for inputs (44).

The review identified only one example of routine data sources being used to construct effective coverage measures of childbirth care. The study, conducted in Mexico, made use of performance indicators from the Mexican Institute of Social Security (IMSS) information system; the only dimension of quality adjusted for was the number of individuals experiencing a positive health outcome (109). The study authors reported that limited data was available to measure quality, which consequently restricted the number of interventions that could be assessed by effective coverage.

Finally, the review underscored the lack of standardised terminology. The term effective coverage was not universally used across studies and no study differentiated between 'intervention' and 'quality' indicators as proposed in the cascade. Items related to these two steps where typically captured under a single domain and defined using a range of terms, including: provision of care (55), competent care (69, 110), systems competence (69), technical quality (25), process quality/indicators (57, 60, 111, 112), receipt of interventions (44, 54, 113), signal functions (52) and clinical care processes (49). The items captured related to the care provided during childbirth, most frequently based on healthcare workers' self-reports of their actions taken.

In undertaking this PhD, the difference between the 'intervention' and 'quality' step in the coverage cascade was identified as not clear cut. To support the mapping and operationalise the cascade in this study, it was therefore necessary to develop definitions to differentiate between these two steps. This was done based on whether the intervention delivered resulted in a direct health benefit (intervention) or whether it enhanced the interaction (process-quality). These definitions were applied throughout the PhD.

8.1.3 Objective 3: estimating effective coverage

Overall, effective coverage of childbirth care in Gombe was very low whether computed using the research project data or data typically available to decision makers in this setting. The analyses point to inadequate service contact (contact coverage) and facility readiness to provide care (input-adjusted coverage), crucial foundations to the provision of high quality care.

Using health facility data (project data) combined with national level population surveys (DHS) it was feasible to measure all steps of the recommended cascade and estimate quality-adjusted coverage for childbirth care. Replicating the analysis using routine data (DHIS2) combined with national level population surveys (DHS), it was possible to measure three steps of the cascade (contact, inputs and intervention) to estimate intervention-adjusted coverage.

The analysis highlights that the data currently available in DHIS2 to estimate inputs was relatively limited and a vital gap in our ability to accurately measure intervention and process quality steps of the cascade. The analysis drew on women's self-reports from NDHS to estimate interventions and no data was available to measure process-quality.

8.1.4 Objective 4: assessing inequalities in effective coverage

Exploratory analysis revealed differences in effective coverage estimates between women from different SES groups; women from more deprived groups were less likely to have received high quality care during childbirth. Undertaking the analysis raised questions about the impact of the methodological approach i.e. relying on summary health data and the ecological linking approach employed, on our ability to examine inequalities and how to interpret the output. Inequalities may be worse than we are able to demonstrate through linking methods at present.

8.2 Strengths and limitations of the approach

A detailed discussion of the limitations of the evidence and methods was presented in each results chapter. Here, I consider the key strengths and limitations to the overall approach taken in the PhD.

First, the coverage cascade developed should not be considered a standardised cascade for childbirth, and it is not a recommendation of this PhD that this is how effective coverage of childbirth care should be measured going forward. I encountered two key issues to operationalising the coverage cascade for childbirth: (1) the steps of the cascade are not clearly defined and did not align with the terminology used in the existing literature; and (2) there is no standardised set of indicators to measure the individual steps of the cascade.

Particularly challenging was how to differentiate between the 'intervention' (receives the service) and 'quality' (receives services according to quality standards) steps of the cascade. The decision to differentiate between these two steps based on whether the intervention delivered resulted in a direct health benefit or whether it enhanced the interaction was a pragmatic one, based on WHO guidance, which distinguishes between clinical and non-clinical aspects of care during childbirth (70), and approved by CHAT and members of MoNITOR. The approach taken to estimate effective coverage in Gombe, measured using observation data, gives insight into the content of care received relative to guidelines but does not shed light on whether the care received was appropriate.

While every attempt was taken to follow a systematic approach, the absence of a standard set of indicators or a clear consensus in the literature, meant the choice of indicators in the analysis of observations and estimate of effective coverage was necessarily somewhat subjective, and it is reasonable to assume that others following the same methods might

have made different choices. Connected to this, the study was conducted in one state in northeast Nigeria; Gombe is a very low resource setting, and facility based childbirth care is characterised by low access, low quality and high mortality (89). The choice of indicators was decided in collaboration with local decision makers to ensure relevance to the Gombe partnership. As such, the findings on the cascade definition might not be generalisable to other settings.

The choice of indicators will affect the coverage estimate. In this setting, where access and quality of care is low, the items included at different steps in the cascade would be unlikely to alter the conclusions. One study comparing a basic measure of input and process-quality of antenatal and sick child care to a more expanded measure in five African countries found that including more items in the measure of input and process quality did not substantially change the quality-adjusted coverage estimate (114). However, it seems likely in settings where access and quality of care are higher the measure might be more sensitive to changes in items included. The choice of indicators warrants further attention.

Second, the study took advantage of the extensive data that had been collected by the IDEAS project as part of the Gombe partnership. The comprehensive project data offered a unique opportunity to examine the quality of care in detail and construct a comprehensive coverage cascade that goes beyond what is routinely feasible to generate in a low resource setting such as Gombe. Even so there are limitations to the data. The health facility survey provides a snapshot of the availability of essential supplies and commodities on the day of the survey, and thus assumes that availability is constant over time. Clinical observations are subject to the Hawthorn effect, in which birth attendants might change their behaviour as a result of being observed, although given the very low implementation of many interventions the impact of being observed is anticipated to have been minimal. Further, only 59% of women were observed during the first stage of labour; it is not possible to know whether this was a result of women presenting late or observers prioritising women in later stages of childbirth. Non-observation was likely random, and women who were not observed during the first stage of labour are unlikely to systematically differ from those who were observed.

There are increasing calls to make better use of routine data systems for effective coverage measurement. Well-functioning health information systems have been identified as one of the essential health system building blocks (28, 115), yet the ability to use health information systems such as DHIS2 is hampered by the reliability of the data in many settings (116-119). This study benefitted from the work undertaken by the IDEAS study to strengthen the quality of routine facility data, see section 3.3 (97), as such the approach might not be suitable in settings where routine data has not been the focus of a data quality intervention. However, the 14 maternal and newborn indicators examined in the evaluation of the data quality

intervention were not included in the analysis of effective coverage as they are not currently reported in DHIS2 (97). The reliability of DHIS2 items used to measure inputs in the analysis of effective coverage is therefore unknown. Further, the validity study of healthcare worker documentation in the facility register indicated variation in validity of indicators; while validity was high for the main care provider's cadre, maternal background characteristics and newborn outcomes, no validity criteria were met for essential newborn care, a composite indicator of immediate breastfeeding and keeping the baby warm (39).

The analysis of effective coverage using routine data was hampered by limited information captured in DHIS2 to allow measurement of quality of care. While more information was available in the facility register on service delivery that could, in theory, be included in DHIS2, this too was relatively limited. The use of DHS data to estimate intervention-adjusted coverage in the analysis is problematic given the limited number of data points and the wealth of evidence documenting that women cannot accurately report on many aspects of the care received during childbirth (39-42, 120, 121). Other studies have used SPA or SARA data (25, 44, 47, 49), but neither are currently available in Nigeria.

Third, the analysis followed validated ecological methods for linking datasets adjusting for the facility type (53, 58, 60). However, the data sources were not temporally aligned. Contact coverage and receipt of interventions measured in the NDHS captures live births in the preceding five years' (2013 – 18), while the project data and the DHIS2 captured inputs, and in the case of project data receipt of interventions and process of care, at the end of the intervention period in August 2019. Given quality of care is likely to change overtime, the effective coverage estimate is not necessarily representative of the care that the women in the NDHS received. Issues of temporality associated with linking nationally representative surveys have been noted elsewhere (44, 46).

The evaluation of the Gombe partnership (see section 3.2) demonstrated improvements in administration of prophylactic uterotonic, clean cord care, delayed bathing and availability of resuscitation equipment in intervention areas based on women's self-reports in household surveys (89). Averaging the quality of care across facility type (PHC or referral) reduces variation between facilities, and likely resulted in the quality of care being overestimated for some women and underestimated for others. The effective coverage measure constructed using the project facility data is likely to be an overestimate, given 57 out of the 97 PHCs in the health facility survey and all 10 PHCs in the clinical observations were included in the intervention, whereas state-wide intervention PHCs account for only around 12% of PHCs providing intrapartum services. The estimate of effective coverage using routine data is unlikely to have been affected, given all facilities within DHIS2 with at least one delivery were included in the analysis and receipt of interventions was estimated based on women's self-

reports within NDHS. A considerable limitation of the NDHS, as discussed in chapter 7, is that it does not allow for more granular linking; this prohibits examining differences in effective coverage between intervention and non-intervention areas, as well as inequalities in effective coverage.

Finally, the study focused on facility based childbirth care. Childbirth is associated with a high burden of maternal and neonatal morbidity and mortality, as such it represents a high priority health contact. Whilst others have also examined effective coverage of childbirth care, much of the work on improving effective coverage measurement for MNCANH has focused on antenatal care, sick child care and nutrition using nationally representative surveys (122, 123). Observations of childbirth care are not routinely included in SPA and so, as noted above, the available data in this setting offered the opportunity to examine childbirth care in depth.

I restricted the scope of the PhD to the routine care that all women and their babies should receive during childbirth. Women who experienced an adverse event (PPH, eclampsia, referral during labour or after birth) or death were excluded from the analysis of observations of childbirth care and the coverage cascade developed was restricted to the receipt of interventions and processes of care essential to all women and their babies during childbirth (70). Separate coverage cascades would need to be developed for each complication as they require different interventions. The Effective Coverage Think Tank Group recommended selecting tracer complications, for example post-partum haemorrhage, and estimating outcome-adjusted coverage (28). The sample size was too small to allow detailed examination of complications; three percent of women observed experienced a complication across all five time points. Reports of observations that were terminated because the observer intervened were not shared with the IDEAS team, so it is not possible to know the true prevalence of complications in this sample. However, a recent study examining neonatal resuscitation care required a sample of over 23,000 births given the relatively low incidence of resuscitation (124). The examination of effective coverage for complications during childbirth is, therefore, likely to require special studies as many household and health facility surveys will be underpowered given complications during childbirth are relatively rare events.

8.3 Implications for quality of childbirth care in Gombe

Findings from this PhD demonstrate that effective coverage of childbirth care is low in Gombe. There were multiple missed opportunities to safeguard MNH despite the demonstrated improvements in both availability of key commodities and life-saving interventions as a result of the Gombe partnership (89). The effective coverage estimate presented here highlights the need for the Agency to continue these efforts and ensure they

are scaled up to more than one PHC per ward to continue to improve the quality of childbirth care across the State and increase access to high quality care. Further, the high levels of inequalities highlight the need to ensure that poorer women are not being left behind. The in-depth analysis of observations of care found substantial variation in the implementation of evidence-based care, which has also been documented elsewhere (125-128). In particular, implementation was low for measures designed as risk assessments such as asking about complications during current and previous pregnancies, taking mother's temperature and blood pressure, checking foetal heart rate, and checking mother's vital signs and baby's temperature within 15 minutes of birth.

Addressing the low implementation of evidence-based care measures during the initial assessment and postpartum period are not currently a focus of the Gombe partnership, which focused on life-saving interventions and facility readiness for life-saving interventions. The analysis of observations of birth and the estimate of effective coverage indicates that a high proportion of women attending facilities are receiving those clinical interventions delivered at the time of birth. Proper risk assessment is key to identify and manage complications, and is particularly important in this setting where only 37 percent of women attended at least four antenatal care visits and only 10 percent of women and 7 percent of newborns received a postnatal check within two days of birth (103). A priority for the Gombe partnership should be to extend their focus to include basic risk assessment.

The inclusion of multiple time points in the analysis of observations allowed examination of changes over time, which, in the context of the Gombe partnership, provided useful information to local decision makers. Overall, coverage of the 50 measures examined were relatively consistency overtime; the only exceptions were "check's mother's HIV status" and "partograph used to monitor labour", for which the estimate was much lower at the first time point and the confidence intervals did not overlap with the other time points.

The PhD did not seek to examine the reasons why the quality of childbirth care was low or why it might vary, and further research would be needed to assess the determinants of high quality care in this setting. Evidence from elsewhere demonstrates that both health facility and birth attendant characteristics can impact the quality of care received (129).

Evidence demonstrates government leadership plays a critical role in influencing quality improvement priorities in health facilities. In Gombe, the Agency has played a central role in shaping the Gombe partnership's improvement activities. Going forward as part of efforts to scale up the Gombe partnership, greater emphasis may also be needed on ensuring adequate facility capacity for quality improvement to allow individual facilities to shape and adapt actions to the facility-level context to maximise health impact (130, 131).

The birth attendant was recorded at the start of the observation period only, so it is not possible to know if women were attended by the same healthcare worker throughout. However, human resources remain a challenge in this setting, with PHCs predominantly staffed by CHEWs and non-skilled birth attendants. The very low implementation of many measures raises questions about the scope of the training package provided to birth attendants. While the relative consistency in coverage of the measures examined, including for a number of practices no longer recommended by WHO, suggest that once in post there may be limited opportunities to improve their skills.

The poor quality of care observed is likely to have an impact on both care seeking and health outcomes. Facility based childbirth has remained low across Gombe and access remains a key bottleneck; concurrent work in this setting and evidence from elsewhere have shown that poor quality of care can deter individuals from seeking care at a health facility (98, 132-139). This suggests that, without efforts to improve the quality of childbirth care, it may actually undermine efforts to encourage facility based care in this setting.

8.4 Implications for effective coverage measurement childbirth care

The drop in coverage observed after adjusting for the quality of care (facility readiness, interventions received and process-quality) underlines calls to shift from contact to effective coverage measures (21, 108).

The findings from this PhD highlight three key challenges that have implications on the feasibility of constructing effective coverage measures of childbirth and consequently the utility of these measures: (1) no standard definitions or use of data sources; (2) insufficient data points to construct comprehensive coverage cascades using routine data source; and (3) limitations to measuring inequalities using current health facility data sources.

Effective coverage measures are anticipated to have utility at the global and national level for tracking performance and benchmarking, as well as sub-national levels where a detailed breakdown of the cascade could be used to identify potential bottlenecks in service provision and support improvement activities (28). My findings have implications on the utility of effective coverage at each level. In the rest of this section, I briefly consider the three implications identified and the impact on utility at different levels.

8.4.1 Lack of standardisation of approach

While there has been considerable progress at the global level to develop standardised measurement approaches for effective coverage (21, 28, 31, 33), the level of heterogeneity in definitions and data sources used between existing studies, and the challenges faced in developing a cascade for the analysis undertaken here, highlight that efforts to operationalise effective coverage should be seen as ongoing.

The Effective Coverage Think Tank Group should consider reviewing the terminology used to define each step of the proposed coverage cascade. The terms ‘contact coverage’ and ‘intervention coverage’ are often used interchangeably in the literature to denote an unadjusted or crude coverage measure, therefore, the use of an ‘adjusted’ intervention coverage by the Think Tank Group is confusing. Also problematic is the use of the term ‘quality-adjusted coverage’ given the wider conceptualisation of quality as a multi-dimensional concept (see section 1.3.1). The Think Tank provides insufficient guidance on how “receives health services according to standards” should, or could, be measured. In undertaking the systematic review, a point of discussion between the study co-authors was whether quality-adjusted coverage should only be measured using direct observations of care. If this is the case, this is associated with a significant measurement burden; observation data was used in only six of the 33 studies included in the systematic review.

At the global level the approach to measurement should be standardised to ensure comparability of measures over time and across place, and thus keep the spotlight on maternal health and advocate for women’s rights. There is a need to build consensus on a standard set of indicators and the data sources that should be used to calculate each step. However, some have proposed that different indicators are needed to measure quality of care in high and low mortality settings (140). Given countries at different stages of obstetric transition face different challenges and solutions to reducing mortality, it might be more appropriate to develop separate cascades for the five stages of obstetric transition (141). The choice of indicators should be driven by what is available in nationally representative surveys such as DHS, MICS, SPA and SARA, or a core-set of DHIS2 indicators. The mapping of existing studies against the cascade provides a useful starting point for future research and guidance (see appendix 2).

The process for developing the coverage cascade taken in this study (systematic review, cross checking against WHO guidelines on best practice and in consultation with local decision makers) was time consuming. To support use of effective coverage at the national- and sub-national level there is a need to develop practical guidance on how to construct coverage cascades. However, the extent to which it is feasible, or desirable, to generate standard measures at the national and sub-national levels is questionable. At the national level, different countries face different challenges and are taking different approaches to improve the quality of childbirth care. For example, to address healthcare worker shortages, the Nigerian government rolled out enhanced training for CHEWs, as part of its task-shifting policy, and classifies them as skilled birth attendants, although this is out of step with WHO recommendations. Guidance, therefore, needs to consider how coverage cascades might be tailored to ensure relevance to the specific contexts (140, 142).

At the sub-national level, where effective coverage measures are being used for quality improvement initiatives, the tension between the need for standardisation at the global level and the needs of decision makers is likely to be more acute. In Gombe, a very low resource setting, the Gombe partnership focused on a core set of improvement activities. In developing the coverage cascade, several indicators identified through the review and recommended by WHO were excluded. Including these indicators would have resulted in an effective coverage measure of zero; a finding that does not provide useful insight given there is no expectation these items would be in place. Over time, it might be anticipated that the measure will need to be adapted to include more and/or different indicators as the aims of the partnership evolve.

8.4.2 Availability and timeliness of existing data sources

Measuring effective coverage of childbirth requires linking population level data on access to care to information on quality of care from facility level surveys (59). Data on the population in need and care seeking is readily available from nationally representative household surveys such as DHS and MICS, which have both been widely implemented in LMICs, making them invaluable for global monitoring (143, 144). However, the opportunities these offer national and sub-national decision makers are potentially more limited. First data collection is undertaken periodically, typically every five years, which limits utility in settings where quality improvement activities are ongoing (145). More timely data on the population in need and care seeking behaviour may be needed to inform decision makers in this setting. Where more temporal estimates are needed, it may require alternative sources of population data and strengthening of administration data systems, for example CRVS and a programme of household surveys to capture information on care seeking (146-148). However, the WHO Score global report highlights a significant need to strengthen CRVS systems; only 44% of births and 10% of deaths in the WHO Africa region are registered (149).

Linking DHS with health facility assessment data generated a more comprehensive coverage cascade than using routinely available data. However, health facility assessment data is not available in all countries; it's not appropriate for countries to routinely generate the comprehensive data that a focussed research project can collect and whilst intervention and process-quality can be assessed in nationally representative surveys, such as SPA or SARA (44, 49), these have only been conducted in 30 countries – Nigeria has neither – and observations of childbirth care are not part of the standard protocol.

Existing evidence demonstrates the limitations of currently available survey instruments to effectively and comprehensively measure quality of care. Mapping studies have found that most quality indicators collected around the time of childbirth relate to inputs (43, 150). Of

relevance to the cascade, one study mapping SARA and SPA questionnaires against the WHO's quality of care framework for pregnant women and newborns found that neither data source could be used to measure evidence-based practices for routine childbirth care and management of complications. Revisions to SPA have just been released (151, 152). While observations have still not been added as standard for childbirth care, at the launch event it was reported that a greater number of indicators have been added to exit interviews with women to capture experience of care during delivery and newborn care. Further, only 13 countries have data from multiple time points, and they are not coordinated with DHS or MICS which makes effective coverage measures constructed using these two data sources susceptible to issues of temporality (43, 44, 46). For example, one study examining trends in effective coverage of postpartum and sick child care across four waves of DHS data in Rwanda, did not use SPA data as it was only available for one of the four time points (69). As with nationally representative household survey data, these data might not be timely enough to support sub-national decision making.

Unlike nationally representative surveys, DHIS2 is available monthly, which offers opportunities to calculate effective coverage at a frequency of most utility to decision makers. Currently DHIS2 in Gombe does not capture sufficient data points to construct a comprehensive coverage cascade, although some data to capture aspects of intervention and process-quality could potentially feasible be added. For example, data for two priority indicators of life-saving care (receipt of oxytocin to prevent post-partum haemorrhage and essential newborn care) are captured in facility records but not included in the monthly monitoring reports to DHIS2 (39). The inability to accurately measure steps beyond input-adjusted coverage in routine data is likely to limit the utility of effective coverage measures. Evidence demonstrates that measuring inputs alone is not sufficient to estimate the quality of care (153).

Globally, almost 50% of countries have limited capacity to monitor quality of care (149). Given the potential burden posed to health workers by additional data collection and evidence of low quality of data (116-119, 154), any extension of data collection must be locally-led by national and sub-national stakeholders to ensure it is of relevance to local priorities and avoids duplicating or creating parallel reporting systems (155). Evidence from Gombe shows that data was of better quality when aligned with Gombe's health programme priorities and that improvements in data quality can be realised (97, 156).

8.4.3 Gaps in our ability to examine inequalities in effective coverage

DHS and MICS are designed to be representative at both the national and sub-national level and capture information on key measures of equity, this allows examination in disparities at the global level. For example, comparing differences in access to high quality childbirth care

services between the richest and poorest women within a country. At the national level, the units of sampling are not always representative of the administrative units relevant to planning and monitoring of health services (157). In Nigeria, where health is devolved to the State, this is not the case, and these data sources can feasible be used to benchmark performance between States, offering opportunities to identify those States performing more or less well.

At lower units of analysis, however, these data are not representative, which limits the opportunities to examine inequalities. For example, through my participation in the Gombe partnership I have observed that there is considerable appetite for more geographic granularity at a sub-State level; the Agency requested key indicators in the six-monthly results framework be disaggregated by LGA to support more targeted action within the State. Stratified analysis by, for example, SES was of limited interest, as it does not provide the information needed to support service planning. Information on LGA was not available in open access NDHS.

Similar to household surveys, SPA and SARA are based on a nationally representative sample, and only SPA has been sampled to allow sub-national estimates. They are therefore also likely to offer limited utility in examining inequalities at sub-national levels. DHIS2 on the other hand is a census of all facilities, allowing examination of effective coverage measures at the level most useful to decision makers. At present, most routine health facility data sources provide a summary of the quality of care provided at the facility-level and do not report individual-level data needed to examine inequalities within a facility. Relying on summary measures of quality of care ignores variation in the quality of care known to exist between individuals attending the same facility (49, 158). However, innovations, such as DHIS2 Tracker (available in Nigeria since 2020), which take HMIS from aggregate to individual-level data, offer exciting opportunities to examine inequalities within facilities (159).

Current measurement approaches linking household and summary facility data are driven by inequalities in access to high quality care based on information collected in household surveys. Using open access NDHS it was only possible to link women to the average score for the type of health facility (PHC or referral) where they reported seeking care. While stratifying by the type of facility might account for some differences in care seeking behaviour – wealthier women are more likely to bypass facilities or travel outside of their catchment area to seek better care (134, 136, 138, 158) – it will not account for differences in the quality of care received within a facility and so likely underestimates inequalities.

8.5 Implications for effective coverage more broadly

Measurement improvement is an important agenda across global health; and the concept of effective coverage and cascades is not limited to childbirth care. The cascade framework applied here has been proposed for all MNCAHN interventions, and there are examples of similar concepts being developed in different academic fields. Examples can be found in HIV, TB and malaria (160-162). It is highly likely that the implications identified here extend beyond childbirth care.

The siloed approach to the development of cascades is potentially a barrier to adoption, as it adds an additional layer of heterogeneity to those identified in this study. It also does not reflect the reality on the ground where decision makers and their monitoring and evaluation officers will be working across health disciplines. There is a need to work to support greater collaboration between fields, to support more standardisation of coverage cascades beyond MNCAHN to provide a consistent terminology and approach to support uptake at country level.

8.6 Needs for further research

One of the challenges that these implications highlight is how these measures should be taken forward at the different levels.

8.6.1 Utility to and (whether and) how coverage cascades can be applied by national and sub-national decision makers

The value of effective coverage measures remains contentious in 'the real world'; while there have been shifts to generating coverage measures that have adjusted for quality, as seen in the latest DHS data – for example, questions have been added on the content of postnatal care (PNC) for women - there is limited evidence that effective coverage is being calculated outside of global institution or academic research settings.

One exception is the Mexican Ministry of Health, which has been measuring effective coverage for skilled birth attendance, services delivered to premature babies and treatment of acute respiratory infections in children to benchmark performance across States based on the WHO's 2003 framework of effective coverage (27, 109, 163-166); quality is defined as the potential health gain and the other components of the cascade (inputs, interventions, process-quality) are not captured.

At the sub-national level, my involvement in the IDEAS project and participation in the Data Driven Learning Workshops (see section 3.2) has given me some insight into the needs for, and capacity of local decision makers to make use of, effective coverage measures. While the coverage cascade highlighted significant gaps in access to, and provision of, high quality

care, as a standalone tool it is unlikely to provide the Gombe partnership with sufficient granularity to inform the actions needed to improve the quality of care in this setting. Operationalising effective coverage in Gombe, will require the Agency to advocate for the inclusion of indicators to capture all components of the coverage cascade in routine data sources such as DHIS2, and to identify more timely sources of data to measure the population in need to enable more regular tracking of progress. The methods to generate effective coverage cascades are relatively straightforward, and within the Gombe partnership there is likely to be sufficient capacity to generate these measures as a result of the activities of the Gombe partnership.

The global measurement community has committed to support local action and country ownership of the measurement and accountability agenda (115, 142, 155). As part of these efforts, there is a need to explore the relevance and utility of effective coverage measures to national and sub-national decision makers. It is also crucial to ensure that intended users are fully involved in the development of any guidance to ensure that coverage cascades are actionable, responsive to country needs, and interpretable. This includes understanding the level of granularity that would have most utility to decision makers and the capacity to generate such measures.

8.6.2 Inequalities

At present the possibility for exploring inequalities of effective coverage is limited by the data available. This requires additional research examining how inequalities change after adjusting for process and experience of care and the impact of different linking methods on estimates.

As we move towards universal access to care, we need to continue to adjust coverage measures for the process and experience of care for individuals. In the short term, there is a need for greater transparency in the reporting of inequalities when linking datasets to be clear what is driving any observed inequalities and the likely underestimates. Ultimately to accurately capture inequalities in effective coverage measures, investment in health information systems is needed to record the individual data that will enable examination of inequalities within facilities.

9 Conclusions

There has been significant momentum at the global level to develop standardise definitions and promote effective coverage measures, to date different approaches have been taken to define and construct effective coverage measures and a shift in approach will be needed if the Effective Coverage Think Tank's proposed coverage cascade is to be adopted. This requires greater consensus on a standardised approach to measuring each step of the cascade, including indicators and suitable data sources, to ensure that measures generated are comparable for global monitoring. Questions remain about the feasibility and utility of generating standardised measures at the national and sub-national levels, and there is a need to investigate how national and sub-national decision makers can best be supported to adopt effective coverage measures.

Operationalising the coverage cascade to childbirth care in Gombe highlights what is and isn't feasible to measure using data typically available to decision makers. It demonstrated that partial effective measures can be constructed using data sources typically available to decision makers in low resource settings and leads to similar conclusions when compared to the comprehensive cascade. Namely, that the availability of inputs, a crucial foundation to the provision of high quality of care, had not yet been met.

The analysis identified a vital gap in our ability to accurately measure all steps of the cascade. Neither intervention nor process-quality are currently capture in DHIS2, and whilst some data is available in household surveys evidence has shown this is not valid for many indicators related to childbirth. The in-depth analysis of the care provided during childbirth in PHCs in Gombe demonstrates that process-quality lags behind components of intervention-quality; the inability for decision makers to monitor this element in routinely available data is a considerable blind spot.

This study adds to existing calls to continue to support countries to extend routine data systems beyond inputs. Advocacy to include intervention and process-quality indicators could optimise this data source for local decision making and take us a step closer to operationalising effective coverage measurement at the country level.

Finally, there is a limited research agenda focusing on inequalities in effective coverage. Whilst it has been acknowledged that effective coverage should be stratified by key demographic variables to highlight inequalities there has been insufficient acknowledgment of the limitations and implications of relying on summary health facility data. There is a need to be mindful of what stratified analyses are feasible and what they are able to tell us about inequalities in effective coverage. This is clearly an unfinished research agenda that warrants further consideration by the measurement improvement community as we continue to promote the use of effective coverage measures.

References

1. PMNCH. A Global Review of the Key Interventions Related to Reproductive, Maternal, Newborn and Child Health (RMNCH). Geneva, Switzerland: The Partnership for Maternal, Newborn & Child Health. 2011.
2. Akseer N, Lawn JE, Keenan W, Konstantopoulos A, Cooper P, Ismail Z, et al. Ending preventable newborn deaths in a generation. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2015;131 Suppl 1:S43-8.
3. WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. Maternal mortality: Levels and trends. 2000 to 2017. Geneva, Switzerland: World Health Organisation. 2019.
4. Lawn JE, Blencowe H, Waiswa P, Amouzou A, Mathers C, Hogan D, et al. Stillbirths: rates, risk factors, and acceleration towards 2030. The Lancet. 2016;387(10018):587-603.
5. Kruk ME, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-DeWan S, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. The Lancet Global health. 2018;6(11):e1196-e252.
6. Moller AB, Patten JH, Hanson C, Morgan A, Say L, Diaz T, et al. Monitoring maternal and newborn health outcomes globally: a brief history of key events and initiatives. Tropical medicine & international health : TM & IH. 2019;24(12):1342-68.
7. WHO. SDG 3: Ensure healthy lives and promote wellbeing for all at all ages [Internet]. Geneva, Switzerland: World Health Organisation.Available from: https://www.who.int/sdg/targets/en/ (accessed on 25 May 2022).
8. Boerma T, Requejo J, Victora CG, Amouzou A, George A, Agyepong I, et al. Countdown to 2030: tracking progress towards universal coverage for reproductive, maternal, newborn, and child health. The Lancet. 2018;391(10129):1538-48.
9. Moller A-B, Newby H, Hanson C, Morgan A, El Arifeen S, Chou D, et al. Measures matter: A scoping review of maternal and newborn indicators. PloS one. 2018;13(10):e0204763.
10. Moran AC, Moller AB, Chou D, Morgan A, El Arifeen S, Hanson C, et al. 'What gets measured gets managed': revisiting the indicators for maternal and newborn health programmes. Reproductive health. 2018;15(1):19.
11. WHO. Monitoring maternal, newborn and child health: understanding key progress indicators. A report prepared by Countdown for Maternal, Newborn and Child Health, Health Metrics Network and WHO. 2011;Geneva, Switzerland: World Health Organisation.
12. Campbell OM, Calvert C, Testa A, Strehlow M, Benova L, Keyes E, et al. The scale, scope, coverage, and capability of childbirth care. The Lancet. 2016;388(10056):2193-208.
13. Countdown to 2030 Collaboration. Countdown to 2030: tracking progress towards universal coverage for reproductive, maternal, newborn, and child health. The Lancet. 2018;391(10129):1538-48.
14. Gabrysch S, Nesbitt RC, Schoeps A, Hurt L, Soremekun S, Edmond K, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. The Lancet Global health. 2019;7(8):e1074-e87.

15. Montagu D, Sudhinaraset M, Diamond-Smith N, Campbell O, Gabrysch S, Freedman L, et al. Where women go to deliver: understanding the changing landscape of childbirth in Africa and Asia. Health policy and planning. 2017;32(8):1146-52.
16. Randive B, Diwan V, De Costa A. India's Conditional Cash Transfer Programme (the JSY) to Promote Institutional Birth: Is There an Association between Institutional Birth Proportion and Maternal Mortality? PloS one. 2013;8(6):e67452.
17. Scott S, Ronsmans C. The relationship between birth with a health professional and maternal mortality in observational studies: a review of the literature. Tropical medicine & international health : TM & IH. 2009;14(12):1523-33.
18. Bohren MA, Vogel JP, Hunter EC, Lutsiv O, Makh SK, Souza JP, et al. The Mistreatment of Women during Childbirth in Health Facilities Globally: A Mixed-Methods Systematic Review. PLoS Med. 2015;12(6):e1001847; discussion e.
19. Kruk ME, Gage AD, Joseph NT, Danaei G, Garcia-Saiso S, Salomon JA. Mortality due to low-quality health systems in the universal health coverage era: a systematic analysis of amenable deaths in 137 countries. The Lancet. 2018;392(10160):2203-12.
20. Miller S, Abalos E, Chamillard M, Ciapponi A, Colaci D, Comande D, et al. Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide. The Lancet. 2016;388(10056):2176-92.
21. Amouzou A, Leslie HH, Ram M, Fox M, Jiwani SS, Requejo J, et al. Advances in the measurement of coverage for RMNCH and nutrition: from contact to effective coverage. BMJ Global Health. 2019;4(Suppl 4):e001297.
22. Grove J, Claeson M, Bryce J, Amouzou A, Boerma T, Waiswa P, et al. Maternal, newborn, and child health and the Sustainable Development Goals--a call for sustained and improved measurement. The Lancet. 2015;386(10003):1511-4.
23. Marchant T, Bryce J, Victora C, Moran AC, Claeson M, Requejo J, et al. Improved measurement for mothers, newborns and children in the era of the Sustainable Development Goals. Journal of global health. 2016;6(1):010506.
24. Requejo JH, Newby H, Bryce J. Measuring coverage in MNCH: challenges and opportunities in the selection of coverage indicators for global monitoring. PLoS Med. 2013;10(5):e1001416.
25. Leslie HH, Malata A, Ndiaye Y, Kruk ME. Effective coverage of primary care services in eight high-mortality countries. BMJ Global Health. 2017;2(3):e000424.
26. Victora CG, Requejo JH, Barros AJ, Berman P, Bhutta Z, Boerma T, et al. Countdown to 2015: a decade of tracking progress for maternal, newborn, and child survival. The Lancet. 2016;387(10032):2049-59.
27. Murray CJL, Evans DB. Technical Consultation on Effective Coverage in Health Systems. Health systems performance assessment : debates, methods and empiricism. Geneva: World Health Organization; 2003. p. 125-34.
28. Marsh AD, Muzigaba M, Diaz T, Requejo J, Jackson D, Chou D, et al. Effective coverage measurement in maternal, newborn, child, and adolescent health and nutrition: progress, future prospects, and implications for quality health systems. The Lancet Global health. 2020;8(5):e730-e6.
29. Tanahashi T. Health service coverage and its evaluation. Bulletin of the World Health Organization. 1978;56(2):295-303.
30. WHO. Background paper for the Technical Consultation on Effective Coverage of Health Systems, 27-29 August 2001, Rio de Janeiro, Brazil [Internet]. Geneva, Switzerland: World Health Organisation. 2001;Available from: http://citeseerx.ist.psu.edu/viewdoc/download?rep=rep1&type=pdf&doi=10.1.1.111.1239 (accessed on 25 May 2022).
31. Shengelia B, Tandon A, Adams OB, Murray CJL. Access, utilization, quality, and effective coverage: An integrated conceptual framework and measurement strategy. Social science & medicine (1982). 2005;61(1):97-109.
32. WHO, The World Bank. Tracking Universal Health Coverage. First Global Monitoring Report. Geneva, Switzerland: World Health Organisation. 2015.

33. Ng M, Fullman N, Dieleman JL, Flaxman AD, Murray CJL, Lim SS. Effective Coverage: A Metric for Monitoring Universal Health Coverage. PLoS Med. 2014;11(9):e1001730.
34. Hanefeld J, Powell-Jackson T, Balabanova D. Understanding and measuring quality of care: dealing with complexity. Bulletin of the World Health Organization. 2017;95(5):368-74.
35. Moxon SG, Ruysen H, Kerber KJ, Amouzou A, Fournier S, Grove J, et al. Count every newborn; a measurement improvement roadmap for coverage data. BMC Pregnancy Childbirth. 2015;15 Suppl 2:S8.
36. Donabedian A. The quality of care. How can it be assessed? Jama. 1988;260(12):1743-8.
37. Tunçalp Ö, Were W, MacLennan C, Oladapo O, Gülmezoglu A, Bahl R, et al. Quality of care for pregnant women and newborns—the WHO vision. Bjog. 2015;122(8):1045-9.
38. WHO. Standards for improving quality of maternal and newborn care in health facilities. Geneva, Switzerland: World Health Organisation. 2016.
39. Bhattacharya AA, Allen E, Umar N, Usman AU, Felix H, Audu A, et al. Monitoring childbirth care in primary health facilities: a validity study in Gombe State, northeastern Nigeria. Journal of global health. 2019;9(2):020411.
40. Blanc AK, Warren C, McCarthy KJ, Kimani J, Ndwiga C, RamaRao S. Assessing the validity of indicators of the quality of maternal and newborn health care in Kenya. Journal of global health. 2016;6(1):010405.
41. McCarthy KJ, Blanc AK, Warren CE, Kimani J, Mdawida B, Ndwidga C. Can surveys of women accurately track indicators of maternal and newborn care? A validity and reliability study in Kenya. Journal of global health. 2016;6(2):020502.
42. Stanton CK, Rawlins B, Drake M, Dos Anjos M, Cantor D, Chongo L, et al. Measuring coverage in MNCH: testing the validity of women's self-report of key maternal and newborn health interventions during the peripartum period in Mozambique. PloS one. 2013;8(5):e60694.
43. Sheffel A, Karp C, Creanga AA. Use of Service Provision Assessments and Service Availability and Readiness Assessments for monitoring quality of maternal and newborn health services in low-income and middle-income countries. BMJ Global Health. 2018;3(6):e001011.
44. Joseph NT, Piwoz E, Lee D, Malata A, Leslie HH. Examining coverage, content, and impact of maternal nutrition interventions: the case for quality-adjusted coverage measurement. Journal of global health. 2020;10(1):010501.
45. Kanyangarara M, Chou VB, Creanga AA, Walker N. Linking household and health facility surveys to assess obstetric service availability, readiness and coverage: evidence from 17 low- and middle-income countries. Journal of global health. 2018;8(1):010603.
46. Kemp CG, Sorensen R, Puttkammer N, Grand'Pierre R, Honoré JG, Lipira L, et al. Health facility readiness and facility-based birth in Haiti: a maximum likelihood approach to linking household and facility data. Journal of global health reports. 2018;2:e2018023.
47. Nguhiu PK, Barasa EW, Chuma J. Determining the effective coverage of maternal and child health services in Kenya, using demographic and health survey data sets: tracking progress towards universal health coverage. Tropical medicine & international health : TM & IH. 2017;22(4):442-53.
48. Nguyen PH, Khương LQ, Pramanik P, Billah SM, Menon P, Piwoz E, et al. Effective coverage of nutrition interventions across the continuum of care in Bangladesh: insights from nationwide cross-sectional household and health facility surveys. BMJ Open. 2021;11(1):e040109.
49. Sharma J, Leslie HH, Kundu F, Kruk ME. Poor Quality for Poor Women? Inequities in the Quality of Antenatal and Delivery Care in Kenya. PloS one. 2017;12(1):e0171236.
50. Wang W, Mallick L, Allen C, Pullum T. Effective coverage of facility delivery in Bangladesh, Haiti, Malawi, Nepal, Senegal, and Tanzania. PloS one. 2019;14(6):e0217853.

51. Carter ED, Leslie HH, Marchant T, Amouzou A, Munos MK. Methodological considerations for linking household and healthcare provider data for estimating effective coverage: a systematic review. BMJ Open. 2021;11(8):e045704.
52. Nesbitt RC, Lohela TJ, Manu A, Vesel L, Okyere E, Edmond K, et al. Quality along the continuum: a health facility assessment of intrapartum and postnatal care in Ghana. PloS one. 2013;8(11):e81089.
53. Willey B, Waiswa P, Kajjo D, Munos M, Akuze J, Allen E, et al. Linking data sources for measurement of effective coverage in maternal and newborn health: what do we learn from individual- vs ecological-linking methods? Journal of global health. 2018;8(1):010601.
54. Baker U, Peterson S, Marchant T, Mbaruku G, Temu S, Manzi F, et al. Identifying implementation bottlenecks for maternal and newborn health interventions in rural districts of the United Republic of Tanzania. Bulletin of the World Health Organization. 2015;93(6):380-9.
55. Larson E, Vail D, Mbaruku GM, Mbatia R, Kruk ME. Beyond utilization: measuring effective coverage of obstetric care along the quality cascade. International journal for quality in health care : journal of the International Society for Quality in Health Care. 2017;29(1):104-10.
56. Kruk ME, Leslie HH, Verguet S, Mbaruku GM, Adanu RMK, Langer A. Quality of basic maternal care functions in health facilities of five African countries: an analysis of national health system surveys. The Lancet Global health. 2016;4(11):e845-e55.
57. Marchant T, Tilley-Gyado RD, Tessema T, Singh K, Gautham M, Umar N, et al. Adding content to contacts: measurement of high quality contacts for maternal and newborn health in Ethiopia, north east Nigeria, and Uttar Pradesh, India. PloS one. 2015;10(5):e0126840.
58. Carter ED, Ndhlovu M, Eisele TP, Nkhama E, Katz J, Munos M. Evaluation of methods for linking household and health care provider data to estimate effective coverage of management of child illness: results of a pilot study in Southern Province, Zambia. Journal of global health. 2018;8(1):010607.
59. Do M, Micah A, Brondi L, Campbell H, Marchant T, Eisele T, et al. Linking household and facility data for better coverage measures in reproductive, maternal, newborn, and child health care: systematic review. Journal of global health. 2016;6(2):020501.
60. Munos MK, Maiga A, Do M, Sika GL, Carter ED, Mosso R, et al. Linking household survey and health facility data for effective coverage measures: a comparison of ecological and individual linking methods using the Multiple Indicator Cluster Survey in Côte d'Ivoire. Journal of global health. 2018;8(2):020803.
61. Kruk ME, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-DeWan S, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. The Lancet Global health. 2018.
62. Requejo J, Diaz T, Park L, Chou D, Choudhury A, Guthold R, et al. Assessing coverage of interventions for reproductive, maternal, newborn, child, and adolescent health and nutrition. BMJ. 2020;368:l6915.
63. WHO. Inequality monitoring in sexual, reproductive, maternal, newborn, child and adolescent health: a step-by-step manual. Geneva, Switzerland: World Health Organisation. 2022.
64. Barros AJ, Victora CG. Measuring coverage in MNCH: determining and interpreting inequalities in coverage of maternal, newborn, and child health interventions. PLoS Med. 2013;10(5):e1001390.
65. Countdown to 2030 Collaboration. Equity: Data & Analysis Center [Internet].Available from: https://www.countdown2030.org/tools-for-analysis/equity-data-analysis-center-2 (accessed 11 May 2022).
66. Faye CM, Wehrmeister FC, Melesse DY, Mutua MKK, Maïga A, Taylor CM, et al. Large and persistent subnational inequalities in reproductive, maternal, newborn and child health intervention coverage in sub-Saharan Africa. BMJ Global Health. 2020;5(1):e002232.
67. Anindya K, Marthias T, Vellakkal S, Carvalho N, Atun R, Morgan A, et al. Socioeconomic inequalities in effective service coverage for reproductive, maternal,

newborn, and child health: a comparative analysis of 39 low-income and middle-income countries. EClinicalMedicine. 2021;40:101103.
68. Arsenault C, Jordan K, Lee D, Dinsa G, Manzi F, Marchant T, et al. Equity in antenatal care quality: an analysis of 91 national household surveys. The Lancet Global health. 2018;6(11):e1186-e95.
69. Hategeka C, Arsenault C, Kruk ME. Temporal trends in coverage, quality and equity of maternal and child health services in Rwanda, 2000-2015. BMJ Global Health. 2020;5(11):e002768.
70. WHO. WHO recommendations: intrapartum care for a positive childbirth experience. Geneva, Switzerland: World Health Organization. 2018.
71. WHO. Managing complications in pregnancy and childbirth: A guide for midwives and doctors. Geneva, Switzerland: World Health Organisation. 2017.
72. Exley J, Bhattacharya AA, Hanson C, Shuaibu A-W, Umar N, Marchant T. Operationalising effective coverage measurement of facility based childbirth in Gombe State; a comparison of data sources. PLOS Global Public Health. 2022.
73. Exley J, Gupta PA, Schellenberg J, Strong K, Requejo J, Moller AB, et al. A rapid systematic review and evidence synthesis of effective coverage measures and cascades for childbirth, newborn and child health in low- and middle-income countries. Journal of global health. 2021;12.
74. Exley J, Hanson C, Umar N, Willey B, Shuaibu A, Marchant T. Provision of essential evidence-based interventions during facility-based childbirth: cross-sectional observations of births in northeast Nigeria. BMJ Open. 2020;10(10):e037625.
75. Exley J, Marchant T. Inequalities in effective coverage measures: are we asking too much of the data? BMJ Global Health. 2022;7(5):e009200.
76. Gombe State Government. History of Gombe State, Nigeria [Internet].Available from: http://gombestate.gov.ng/history-2/ (accessed on 25 May 2022).
77. Marchant T. Change in maternal and newborn health care. Interactions between families and frontline workers - their frequency, quality and equity - and coverage of interventions of mothers and newborns. Report from Gombe State, Nigeria, 2012-2015 [Internet]. IDEAS, London School of Hygiene & Tropical Medicine. 2016;Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/08/Marchant_IDEAS_Gombe_State_Follow-upSurvey_2016.pdf (accessed on 25 May 2022).
78. Izugbara CO, Wekesah FM, Adedini SA. Maternal Health in Nigeria. A Situation Update. Nairobi, Kenya: African Population and Health Research Centre; 2016.
79. National Bureau of Statistics (NBS) and United Nations Children's Fund (UNICEF). Multiple Indicator Cluster Survey 2016-17, Survey Findings Report. Abuja, Nigeria: National Bureau of Statistics and United Nations Children's Fund. 2017.
80. Bhattacharya AA, Umar N, Audu A, Felix H, Allen E, Schellenberg JRM, et al. Quality of routine facility data for monitoring priority maternal and newborn indicators in DHIS2: A case study from Gombe State, Nigeria. PloS one. 2019;14(1):e0211265.
81. National Population Commission and ICF. Nigeria Demographic and Health Survey 2018. Key Indicators Report. Abuja, Nigeria, and Rockville, Maryland, USA; 2019.
82. Nigeria Health Management Information System. Gombe State facility deliveries, by facility type, January-December 2018. Nigeria District Health Information System, version 2. 2019.
83. Federal Government of Nigeria. Second National Strategic Health Development Plan 2018-2022. Ensuring healthy lives and promoting the wellbeing of Nigerian populace at all ages. Abuja, Nigeria: Federal Ministry of Health. 2019.
84. Federal Ministry of Health. Task-shifting and task-sharing policy for essential health care services in Nigeria. Abuja, Nigeria. 2014;Available from: https://advancefamilyplanning.org/sites/default/files/resources/Nigeria%20taskshifting%20policy-Aug2014%20REVISEDCLEAN%20_Approved%20October%202014.pdf (accessed on 17 October 2022).

85. E4A-MamaYe. Gombe PHC stockout of essential life-saving commodities scorecards. Jan - June 2018 [Internet]. 2018;Available from: https://mamaye.org/resources/scorecards/gombe-phc-stockout-essential-life-saving-commodities-scorecard (accessed on 16 April 2022).
86. IDEAS team. Informed Decisions for Actions in Maternal and Newborn Health 2010-17 Report: What works, why and how in maternal and newborn health [Internet]. IDEAS, London School of Hygiene & Tropical Medicine. 2017;Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/09/LSHTM_IDEAS_PhaseIReport_Web-reduced.pdf (accessed on 25 May 2022).
87. Makowiecka K, Marchant T, Betemariam W, Chaturvedi A, Jana L, Liman A, et al. Characterising innovations in maternal and newborn health based on a common theory of change: lessons from developing and applying a characterisation framework in Nigeria, Ethiopia and India. BMJ Global Health. 2019;4(4):e001405.
88. Makowiecka K. The Pathway to Improved Maternal and Newborn Health Outcomes. Use of data for maternal and newborn health in Gombe State, Nigeria [Internet]. IDEAS, London School of Hygiene & Tropical Medicine. 2016;Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2017/08/Makowiecka_IDEAS_Pathway_Improved_Maternal_Newborn_Health_Gombe_Nigeria_2016.pdf (accessed on 25 May 2022).
89. Willey B, Umar N, Beaumont E, Allen E, Anyanti J, Bello AB, et al. Improving maternal and newborn health services in Northeast Nigeria through a government-led partnership of stakeholders: a quasi-experimental study. BMJ Open. 2022;12(2):e048877.
90. Wickremasinghe D, Alkali Hamza Y, Umar N, Willey B, Okolo M, Gana A, et al. 'A seamless transition': how to sustain a community health worker scheme within the health system of Gombe state, northeast Nigeria. Health policy and planning. 2021;36(7):1067-76.
91. pact. Pact mothers group becomes a leader in community development [Internet]. 2019;Available from: https://www.pactworld.org/features/pact-mothers-group-becomes-leader-community-development (accessed on 17 October 2022].
92. Shobo OG, Umar N, Gana A, Longtoe P, Idogho O, Anyanti J. Factors influencing the early initiation of breast feeding in public primary healthcare facilities in Northeast Nigeria: a mixed-method study. BMJ Open. 2020;10(4):e032835.
93. Makowiecka K. Collaborative Learning in Gombe [Internet]. IDEAS, London School of Hygiene & Tropical Medicine. 2019;Available from: https://ideas.lshtm.ac.uk/collaborative-learning-in-gombe/ (accessed on 17 October 2022).
94. Makowiecka K. How have data-driven learning workshops contributed to the work of the Gombe State Primary Health Care Development Agency and its partners in enhancing the health of women and newborns in the State? [Internet]. IDEAS, London School of Hygiene & Tropical Medicine. 2019;Available from: https://ideas.lshtm.ac.uk/how-do-data-driven-learning-cycles-have-an-impact/ (accessed on 17 October 2022).
95. Makowiecka K. The effect of participating in a data-driven learning cycle on data use for decision making in maternal and newborn health. Gombe State, Nigeria. IDEAS, London School of Hygiene & Tropical Medicine. 2018;Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2018/05/Research-Brief_Decision-makingFinal.pdf (accessed on 17 October 2022).
96. IDEAS team. Project website [Internet]. IDEAS, London School of Hygiene & Tropical Medicine.Available from: https://ideas.lshtm.ac.uk/ (accessed on 25 May 2022).
97. Bhattacharya AA, Allen E, Umar N, Audu A, Felix H, Schellenberg J, et al. Improving the quality of routine maternal and newborn data captured in primary health facilities in Gombe State, Northeastern Nigeria: a before-and-after study. BMJ Open. 2020;10(12):e038174.
98. Umar N, Quaife M, Exley J, Shuaibu A, Hill Z, Marchant T. Toward improving respectful maternity care: a discrete choice experiment with rural women in northeast Nigeria. BMJ Global Health. 2020;5(3):e002135.

99. Umar N, Wickremasinghe D, Hill Z, Usman UA, Marchant T. Understanding mistreatment during institutional delivery in Northeast Nigeria: a mixed-method study. Reproductive health. 2019;16(1):174.
100. The Demographic and Health Surveys Program. DHS Model Questionnaires [Internet].Available from: https://dhsprogram.com/What-We-Do/Survey-Types/DHS-Questionnaires.cfm (accessed on 25 May 2022).
101. WHO. Service Availability and Readiness Assessment (SARA). An annual monitoring system for service delivery. Reference Manual [Internet]. Geneva, Switzerland: World Health Organisation 2015;Available from: https://apps.who.int/iris/handle/10665/149025 (accessed on 17 January 2022).
102. USAID. Maternal and Newborn Quality of Care Surveys [Internet]. Maternal and Child Health Integrated Program. 2013;Available from: https://www.mchip.net/qocsurveys/ (accessed on 14 April 2022).
103. National Population Commission - NPC, ICF. Nigeria Demographic and Health Survey 2018 - Final Report. Abuja, Nigeria: NPC and ICF; 2019.
104. DHIS2. About DHIS2 [Internet]. HISP Centre, University of Oslo Available from: https://dhis2.org/about/ (accessed on 11 Oct 2021).
105. Vyas S, Kumaranayake L. Constructing socio-economic status indices: how to use principal components analysis. Health policy and planning. 2006;21(6):459-68.
106. Marchant T, Schellenberg D, Nathan R, Armstrong-Schellenberg J, Mponda H, Jones C, et al. Assessment of a national voucher scheme to deliver insecticide-treated mosquito nets to pregnant women. CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne. 2010;182(2):152-6.
107. Day LT, Ruysen H, Gordeev VS, Gore-Langton GR, Boggs D, Cousens S, et al. "Every Newborn-BIRTH" protocol: observational study validating indicators for coverage and quality of maternal and newborn health care in Bangladesh, Nepal and Tanzania. Journal of global health. 2019;9(1):010902.
108. Jannati A, Sadeghi V, Imani A, Saadati M. Effective coverage as a new approach to health system performance assessment: a scoping review. BMC Health Services Research. 2018;18(1):886.
109. Leslie HH, Doubova SV, Pérez-Cuevas R. Assessing health system performance: effective coverage at the Mexican Institute of Social Security. Health policy and planning. 2019;34(Supplement_2):ii67-ii76.
110. Okawa S, Win HH, Leslie HH, Nanishi K, Shibanuma A, Aye PP, et al. Quality gap in maternal and newborn healthcare: a cross-sectional study in Myanmar. BMJ Global Health. 2019;4(2):e001078.
111. Koulidiati JL, Nesbitt RC, Ouedraogo N, Hien H, Robyn PJ, Compaoré P, et al. Measuring effective coverage of curative child health services in rural Burkina Faso: a cross-sectional study. BMJ Open. 2018;8(5):e020423.
112. Murphy GAV, Gathara D, Mwachiro J, Abuya N, Aluvaala J, English M. Effective coverage of essential inpatient care for small and sick newborns in a high mortality urban setting: a cross-sectional study in Nairobi City County, Kenya. BMC Med. 2018;16(1):72.
113. Carvajal-Aguirre L, Amouzou A, Mehra V, Ziqi M, Zaka N, Newby H. Gap between contact and content in maternal and newborn care: An analysis of data from 20 countries in sub-Saharan Africa. Journal of global health. 2017;7(2):020501.
114. Riese S, Assaf S, Pullum T. Measurement Approaches for Effective Coverage Estimation. DHS Methodological Reports No 31. 2021;Rockville, Maryland, USA: ICF.
115. WHO. Everybody's business: strengthening health systems to improve health outcomes: WHO's framework for action. Geneva, Switzerland: World Health Organisation. 2007.
116. Adane A, Adege TM, Ahmed MM, Anteneh HA, Ayalew ES, Berhanu D, et al. Routine health management information system data in Ethiopia: consistency, trends, and challenges. Glob Health Action. 2021;14(1):1868961.

117. Garrib A, Stoops N, McKenzie A, Dlamini L, Govender T, Rohde J, et al. An evaluation of the District Health Information System in rural South Africa. South African medical journal = Suid-Afrikaanse tydskrif vir geneeskunde. 2008;98(7):549-52.
118. Maïga A, Jiwani SS, Mutua MK, Porth TA, Taylor CM, Asiki G, et al. Generating statistics from health facility data: the state of routine health information systems in Eastern and Southern Africa. BMJ Global Health. 2019;4(5):e001849.
119. Mate KS, Bennett B, Mphatswe W, Barker P, Rollins N. Challenges for routine health system data management in a large public programme to prevent mother-to-child HIV transmission in South Africa. PloS one. 2009;4(5):e5483.
120. Carter ED, Ndhlovu M, Munos M, Nkhama E, Katz J, Eisele TP. Validity of maternal report of care-seeking for childhood illness. Journal of global health. 2018;8(1):010602.
121. Carter ED, Chang KT, Mullany LC, Khatry SK, LeClerq SC, Munos MK, et al. Reliability of maternal recall of delivery and immediate newborn care indicators in Sarlahi, Nepal. BMC Pregnancy and Childbirth. 2021;21(1):82.
122. Improving Measurement and Program Design (Improve). Improved quality and availability of MNCH & Nutrition intervention coverage estimates [Internet]. John Hopkins Bloomberg School of Public Health.Available from: https://www.jhsph.edu/research/centers-and-institutes/institute-for-international-programs/current-projects/improving-measurement-and-program-design/improved-quality-and-availability-of-mnch-nutrition-intervention-coverage-estimates.html (accessed on 23 May 2022).
123. Countdown to 2030 Collaboration. Effective Coverage: data & analysis center [Internet].Available from: https://www.countdown2030.org/tools-for-analysis/effective-coverage-data-analysis-center (accessed on 23 May 2022).
124. Kc A, Peven K, Ameen S, Msemo G, Basnet O, Ruysen H, et al. Neonatal resuscitation: EN-BIRTH multi-country validation study. BMC Pregnancy Childbirth. 2021;21(Suppl 1):235.
125. de Graft-Johnson J, Vesel L, Rosen HE, Rawlins B, Abwao S, Mazia G, et al. Cross-sectional observational assessment of quality of newborn care immediately after birth in health facilities across six sub-Saharan African countries. BMJ Open. 2017;7(3):e014680.
126. Rawlins B, Plotkin M, Rakotovao JP, Getachew A, Vaz M, Ricca J, et al. Screening and management of pre-eclampsia and eclampsia in antenatal and labor and delivery services: findings from cross-sectional observation studies in six sub-Saharan African countries. BMC Pregnancy Childbirth. 2018;18(1):346.
127. Saxena M, Srivastava A, Dwivedi P, Bhattacharyya S. Is quality of care during childbirth consistent from admission to discharge? A qualitative study of delivery care in Uttar Pradesh, India. PloS one. 2018;13(9):e0204607.
128. Sharma G, Powell-Jackson T, Haldar K, Bradley J, Filippi V. Quality of routine essential care during childbirth: clinical observations of uncomplicated births in Uttar Pradesh, India. Bulletin of the World Health Organization. 2017;95(6):419-29.
129. Millogo T, Kourouma RK, Méda BI, Agbre-Yace ML, Dosso A, Yaméogo MWE, et al. Determinants of childbirth care quality along the care continuum in limited resource settings: A structural equation modeling analysis of cross-sectional data from Burkina Faso and Côte d'Ivoire. BMC Pregnancy Childbirth. 2021;21(1):848.
130. Olaniran AA, Oludipe M, Hill Z, Ogunyemi A, Umar N, Ayorinde R, et al. Influence of context on quality improvement priorities: a qualitative study of three facility types in Lagos State, Nigeria. BMJ open quality. 2022;11(1).
131. Olaniran AA, Oludipe M, Hill Z, Ogunyemi A, Umar N, Ohiri K, et al. From Theory to Implementation: Adaptations to a Quality Improvement Initiative According to Implementation Context. Qualitative health research. 2022;32(4):646-55.
132. Hanson K, McPake B, Nakamba P, Archard L. Preferences for hospital quality in Zambia: results from a discrete choice experiment. Health economics. 2005;14(7):687-701.
133. Karkee R, Lee AH, Binns CW. Bypassing birth centres for childbirth: an analysis of data from a community-based prospective cohort study in Nepal. Health policy and planning. 2015;30(1):1-7.

134. Kruk ME, Hermosilla S, Larson E, Mbaruku GM. Bypassing primary care clinics for childbirth: a cross-sectional study in the Pwani region, United Republic of Tanzania. Bulletin of the World Health Organization. 2014;92(4):246-53.
135. Larson E, Gage AD, Mbaruku GM, Mbatia R, Haneuse S, Kruk ME. Effect of a maternal and newborn health system quality improvement project on the use of facilities for childbirth: a cluster-randomised study in rural Tanzania. Tropical medicine & international health : TM & IH. 2019;24(5):636-46.
136. Mubiri P, Kajjo D, Okuga M, Marchant T, Peterson S, Waiswa P, et al. Bypassing or successful referral? A population-based study of reasons why women travel far for childbirth in Eastern Uganda. BMC Pregnancy and Childbirth. 2020;20(1):497.
137. Peet ED, Okeke EN. Utilization and quality: How the quality of care influences demand for obstetric care in Nigeria. PloS one. 2019;14(2):e0211500.
138. Rao KD, Sheffel A. Quality of clinical care and bypassing of primary health centers in India. Social science & medicine (1982). 2018;207:80-8.
139. Shah R. Bypassing birthing centres for child birth: a community-based study in rural Chitwan Nepal. BMC Health Services Research. 2016;16(1):597.
140. Koblinsky M, Moyer CA, Calvert C, Campbell J, Campbell OMR, Feigl AB, et al. Quality maternity care for every woman, everywhere: a call to action. The Lancet. 2016;388(10057):2307-20.
141. Souza JP, Tunçalp Ö, Vogel JP, Bohren M, Widmer M, Oladapo OT, et al. Obstetric transition: the pathway towards ending preventable maternal deaths. Bjog. 2014;121 Suppl 1:1-4.
142. Marchant T, Boerma T, Diaz T, Huicho L, Kyobutungi C, Mershon CH, et al. Measurement and accountability for maternal, newborn and child health: fit for 2030? BMJ Global Health. 2020;5(7).
143. The Demographic and Health Surveys Program. The DHS Program: Country List [Internet]. Rockville; USAID.Available from: https://www.dhsprogram.com/Countries/Country-List.cfm (accessed on 11 October 2021).
144. UNICEF. About MICS [Internet].Available from: https://mics.unicef.org/about (cited 14 Oct 2021).
145. Zhao L, Cao B, Borghi E, Chatterji S, Garcia-Saiso S, Rashidian A, et al. Data gaps towards health development goals, 47 low- and middle-income countries. Bulletin of the World Health Organization. 2022;100(1):40-9.
146. AbouZahr C, Boerma T. Health information systems: the foundations of public health. Bulletin of the World Health Organization. 2005;83(8):578-83.
147. UN. Demographic and Social Statistics: Civil Registration and Vital Statistics. Statistics Division, New York: United Nations. 2016;Available from: https://unstats.un.org/unsd/demographic-social/crvs/ (accessed on 16 April 2022).
148. Yokobori Y, Obara H, Sugiura Y, Kitamura T. Gaps in the civil registration and vital statistics systems of low- and middle-income countries and the health sector's role in improving the situation. Glob Health Med. 2021;3(4):243-5.
149. WHO. SCORE for health data technical package: global report on health data systems and capacity, 2020. Geneva, Switzerland: World Health Organisation. 2021.
150. Brizuela V, Leslie HH, Sharma J, Langer A, Tunçalp Ö. Measuring quality of care for all women and newborns: how do we know if we are doing it right? A review of facility assessment tools. The Lancet Global Health. 2019;0(0).
151. USAID. SPA Overview [Internet]. 2022;Available from: https://dhsprogram.com/Methodology/Survey-Types/SPA.cfm (accessed on 23 May 2022).
152. USAID. SPA Questionnaires. 2022;Available from: https://dhsprogram.com/Methodology/Survey-Types/SPA-Questionnaires.cfm (accessed on 23 May 2022).
153. Leslie HH, Sun Z, Kruk ME. Association between infrastructure and observed quality of care in 4 healthcare services: A cross-sectional study of 4,300 facilities in 8 countries. PLoS Med. 2017;14(12):e1002464.

154. Siyam A, Ir P, York D, Antwi J, Amponsah F, Rambique O, et al. The burden of recording and reporting health data in primary health care facilities in five low- and lower-middle income countries. BMC Health Services Research. 2021;21(1):691.
155. Diaz T, Requejo J. Improving analysis and use of routine reproductive, maternal, newborn, and child health facility data in low-and middle-income countries: a universal priority. BMC Health Services Research. 2021;21(1):604.
156. Bhattacharya AA. Strengthening the quality of routine maternal and newborn health data through learning workshops in Gombe, Nigeria [Internet]. IDEAS, London School of Hygiene & Tropical Medicine. 2018;Available from: https://ideas.lshtm.ac.uk/wp-content/uploads/2019/03/DQLW4_Report-2019.pdf (accessed on 25 May 2022).
157. Nilsen K, Tejedor-Garavito N, Leasure DR, Utazi CE, Ruktanonchai CW, Wigley AS, et al. A review of geospatial methods for population estimation and their use in constructing reproductive, maternal, newborn, child and adolescent health service indicators. BMC Health Services Research. 2021;21(1):370.
158. Fink G, Kandpal E, Shapira G. Inequality in the Quality of Health Services: Wealth, Content of Care, and Price of Antenatal Consultations in the Democratic Republic of Congo. Policy Research Working Papers. 2019;No 8818(World Bank, Washington, DC).
159. DHIS2. Individual Data Records with Tracker [Internet]. HISP Centre, University of Oslo.AVailable from: https://dhis2.org/tracker/ (accessed on 23 May 2022).
160. Ehrenkranz P, Rosen S, Boulle A, Eaton JW, Ford N, Fox MP, et al. The revolving door of HIV care: Revising the service delivery cascade to achieve the UNAIDS 95-95-95 goals. PLoS Med. 2021;18(5):e1003651.
161. Hargreaves J, Auerback J, Hensen B, Gregson S. Special Issue: Data-driven HIV prevention: the HIV prevention cascade and beyond. Journal of the International Aids Society. 2020;23(S3).
162. Smith LA, Bruce J, Gueye L, Helou A, Diallo R, Gueye B, et al. From fever to anti-malarial: the treatment-seeking process in rural Senegal. Malar J. 2010;9(1):333.
163. Gakidou E, Lozano R, Gonzalez-Pier E, Abbott-Klafter J, Barofsky JT, Bryson-Cahn C, et al. Assessing the effect of the 2001-06 Mexican health reform: an interim report card. The Lancet. 2006;368(9550):1920-35.
164. Lozano R, Soliz P, Gakidou E, Abbott-Klafter J, Feehan DM, Vidal C, et al. Benchmarking of performance of Mexican states with effective coverage. The Lancet. 2006;368(9548):1729-41.
165. Serván-Mori E, Cerecero-García D, Heredia-Pi IB, Pineda-Antúnez C, Sosa-Rubí SG, Nigenda G. Improving the effective maternal-child health care coverage through synergies between supply and demand-side interventions: evidence from Mexico. Journal of global health. 2019;9(2):020433.
166. Serván-Mori E, Contreras-Loya D, Gomez-Dantés O, Nigenda G, Sosa-Rubí SG, Lozano R. Use of performance metrics for the measurement of universal coverage for maternal care in Mexico. Health policy and planning. 2017;32(5):625-33.

Appendices

The following appendices present the supplementary material that accompanied the three published manuscripts associated with objectives 1 to 3.

Appendix 1 - Supplementary material: objective 1

Supplementary material: full table of results

	Observation period				
	1 (Aug 2016)	**2 (Mar 2017)**	**3 (Aug 2017)**	**4 (Mar 2018)**	**5 (Aug 2018)**
	Percentage of women (95%CI)				
History taking & initial assessment					
Encourages woman to have a support person	70.8% (50.0-85.5)	57.1% (31.1-79.7)	48.6% (28.0-69.6)	62.6% (45.0-77.4)	77.1% (67.8-84.4)
Asks if have any questions	34.8% (22.7-49.3)	30.0% (12.6-56.2)	16.6% (8.5-29.9)	25.7% (16.5-37.6)	53.4% (37.5-68.6)
Checks client card or asks client age, length of pregnancy and parity	73.2% (53.4-86.7)	82.3% (61.4-93.0)	74.4% (48.2-90.1)	85.3% (74.5-92.1)	85.0% (71.4-92.8)
Checks woman's HIV status	3.0% (1.4-6.3)	24.8% (12.8-42.6)	60.4% (40.9-77.0)	52.3% (32.4-71.6)	67.2% (56.1-76.6)
Asks whether experienced any complications during pregnancy	13.7% (7.9-22.8)	12.8% (7.1-22.1)	9.6% (4.0-20.9)	12.0% (7.2-19.3)	12.6% (6.6-22.7)
If had a previous pregnancy, whether experienced any complications during previous pregnancies	14.6% (9.5-21.8)	17.5% (8.1-34.0)	15.5% (10.3-22.6)	21.8% (14.7-31.0)	21.4% (13.9-31.6)
Health worker washes hands	25.3% (12.6-44.4)	13.4% (5.4-29.4)	11.5% (4.8-25.3)	50.9% (28.8-72.6)	37.2% (23.2-53.8)
Explains procedure to woman before proceeding	69.4% (55.6-80.3)	72.7% (52.3-86.6)	50.0% (27.6-72.4)	60.4% (42.9-75.6)	80.4% (73.3-85.9)
Performs vaginal examination	99.1% (96.6-99.8)	97.5% (94.2-998.9)	98.3% (95.8-99.3)	97.6% (94.2-99.0)	98.5% (97.0-99.3)
If performs vaginal exam, wears high-level disinfectant gloves	93.7% (82.8-97.9)	79.7% (48.6-94.2)	94.9% (84.3-98.5)	43.9% (21.3-69.3)	59.2% (35.9-79.0)
Takes temperature	0.6% (0.2-1.9)	1.1% (0.3-4.1)	3.4% (0.7-14.5)	8.3% (3.1-20.6)	4.7% (1.0-19.0)
Takes blood pressure	24.7% (11.2-46.0)	26.2% (11.0-50.5)	18.3% (9.2-33.0)	50.4% (33.1-67.6)	26.7% (11.7-50.0)
Checks foetal heart rate with fetoscope/Doppler/ultrasound	28.0% (14.0-48.0)	17.3% (7.2-36.0)	9.3% (3.4-23.0)	33.8% (21.0-49.4)	19.9% (11.0-33.5)

First stage of labour: examination and procedures					
Partograph used to monitor labour	0.6% (0.1-4.8)	32.3% (14.0-58.3)	29.1% (14.6-49.7)	37.1% (26.6-49.0)	15.4% (7.7-28.6)
Washes hands with soap & water or uses antiseptic prior to any examination of woman	37.2% (19.9-58.7)	21.7% (11.3-37.6)	14.3% (5.9-30.7)	57.2% (32.8-78.6)	53.7% (40.3-66.6)
Wears high-level disinfected or surgical gloves	94.2% (80.1-98.5)	88.9% (71.6-96.2)	94.2% (82.5-98.2)	51.6% (26.7-75.7)	65.2% (35.3-86.5)
Median number of vaginal examinations	2 (1-2)	1 (1-2)	2 (1-2)	1 (1-2)	1 (1-2)
Augments labour with oxytocin	14.5% (7.5-26.3)	12.6% (6.5-23.2)	24.9% (17.2-34.5)	18.0% (7.5-37.2)	15.4% (5.9-34.5)
Performs artificial rupture of membranes	7.6% (3.9-14.0)	9.6% (4.3-20.2)	9.0% (3.3-22.5)	3.5% (1.5-7.9)	1.8% (0.4-6.7)
A support person present at some point during labour	69.2% (47.3-84.9)	70.2% (46.8-86.3)	67.7% (46.1-83.7)	70.7% (54.5-82.9)	78.9% (57.8-91.0)
At least once explains what will happen in labour	46.5% (33.2-60.3)	55.1% (35.5-73.2)	33.9% (17.5-55.3)	42.1% (30.5-54.6)	67.0% (57.2-75.5)
At least encouraged to consume fluids/foods during labour	93.6% (90.4-95.8)	79.3% (66.5-88.1)	87.3% (82.4-91.0)	91.9% (84.7-95.8)	92.1% (78.7-97.3)
Drapes woman	28.5% (12.7-52.1)	59.1% (43.3-73.2)	67.7% (45.5-84.1)	53.7% (26.8-78.7)	80.2% (56.9-92.5)
At least once encourages woman to ambulate and assume different positions in labour	69.8% (50.5-83.9)	60.1% (42.8-75.2)	65.6% (41.2-83.9)	79.9% (63.4-90.1)	85.9% (71.7-93.6)
First stage of labour: equipment and supplies laid out in preparation for delivery					
At least two cloths/blankets	91.9% (81.2-96.7)	90.4% (82.7-94.9)	88.9% (58.0-97.9)	85.2% (67.5-94.1)	93.8% (86.6-97.3)
Disposable cord ties or clamps	96.5% (87.1-99.1)	97.0% (93.1-98.7)	98.4% (87.9-99.8)	99.3% (97.4-99.8)	99.6% (97.5-99.9)
Sterile scissors or blade	98.8% (94.9-99.8)	99.0% (96.6-99.7)	100%	98.9% (96.8-99.7)	98.7% (95.5-99.6)
Suction bulb	93.0% (87.3-96.3)	82.3% (71.0-89.9)	84.1% (71.4-91.8)	75.6% (59.1-87.0)	76.7% (44.6-93.0)
Bag & face mask (size 0 or 1)	14.0% (4.7-35.0)	46.0% (26.9-66.2)	50.3% (29.0-71.4)	43.5% (30.4-57.6)	41.0% (17.3-69.7)
Second and third stage of labour					
More than one HCW assist with delivery	60.1% (40.4-77.0)	51.4% (36.6-66.0)	59.8% (48.9-69.9)	62.1% (45.1-76.6)	48.7% (36.7-60.8)

A support person for mother present	42.3% (26.2-60.3)	34.2% (14.2-62.0)	20.5% (9.2-39.6)	34.0% (20.3-51.0)	49.3% (37.0-61.7)
Performs episiotomy	1.5% (0.4-5.4)	0.8% (0.2-4.4)	0.6% (0.1-2.4)	2.4% (1.0-5.8)	0.3% (0-2.6)
Mother gave birth in lithotomy position	97.9% (94.3-99.3)	98.9% (96.2-99.7)	91.9% (78.1-97.3)	95.6% (84.8-98.8)	98.5% (96.4-99.4)
As baby's head is delivered, supports perineum	97.3% (94.7-98.7)	94.7% (91.6-96.7)	84.0% (73.5-90.9)	93.9% (89.7-96.4)	94.1% (87.3-97.4)
Checks for another baby prior to giving the uterotonic	56.8% (31.7-78.9)	50.8% (33.6-67.9)	52.8% (37.9-67.2)	81.2% (59.5-92.7)	83.0% (67.9-91.9)
Received uterotonic	97.3% (95.6-98.4)	95.0% (92.7-96.6)	97.5% (95.4-98.6)	97.1% (92.0-99.0)	93.8% (69.2-99.0)
If uterotonic received, timing of administration					
At delivery	0.3% (0-2.4)	0.3% (0-2.7)	0.3% (0.1-1.3)	1.8% (0.6-5.0)	0
Within 1 minute of delivery	23.0% (9.4-46.4)	8.8% (2.7-25.0)	10.9% (5.8-19.5)	11.1% (4.9-23.1)	16.6% (9.0-28.6)
Within 3 minutes of delivery	28.5% (22.7-35.1)	30.7% (19.7-44.5)	26.1% (18.4-35.6)	37.0% (29.4-45.4)	51.3% (42.1-60.4)
More than 3 minutes	47.6% (31.6-64.1)	60.2% (41.1-76.7)	62.5% (54.0-70.3)	50.1% (37.9-62.4)	32.2% (25.3-39.9)
Applies traction to the cord while applying suprapubic counter traction	87.3% (80.8-91.8)	81.9% (61.9-92.7)	80.6% (70.5-87.9)	85.3% (67.3-94.3)	91.2% (71.7-97.7)
If skilled (doctor, nurse, midwife) birth assistant, applies traction to the cord while applying suprapubic counter traction	100%	95.4% (63.0-99.6)	88.7% (81.9-93.2)	82.4% (77.4-86.4)	90.5% (48.1-99.0)
If CHEW birth assistant, applies traction to the cord while applying suprapubic counter traction	87.6% (78.8-93.0)	80.9% (58.9-92.6)	81.9% (67.4-90.8)	85.7% (54.9-96.7)	88.9% (66.8-97.0)
If unskilled birth assistant, applies traction to the cord while applying suprapubic counter traction	86.1% (78.1-91.5)	77.8% (57.5-90.0)	77.0% (63.8-86.4)	85.2% (65.2-94.7)	93.0% (77.1-98.1)
Performs uterine massage immediately following the delivery of the placenta	73.7% (63.7-81.7)	78.6% (60.7-89.8)	63.8% (52.6-73.6)	79.0% (63.6-89.0)	77.4% (63.4-87.2)
Assesses completeness of placenta and membranes	70.7% (52.8-83.9)	25.8% (16.3-38.3)	32.9% (26.4-40.1)	53.8% (29.8-76.2)	61.6% (36.8-81.5)
Assesses for perineal and vaginal lacerations	90.2% (80.5-95.4)	89.4% (78.5-95.2)	75.0% (47.1-91.0)	90.5% (69.0-97.6)	88.0% (66.8-96.4)
Immediate newborn and postpartum care					
Immediately dries newborn with towel	89.3% (67.8-97.1)	90.5% (73.9-96.9)	93.9% (84.7-97.7)	98.7% (94.5-99.7)	99.4% (95.6-99.9)

Places baby on mother's abdomen "skin-to-skin"	68.1% (30.5-91.2)	49.0% (26.4-72.0)	66.9% (41.6-85.1)	92.8% (85.0-96.7)	92.3% (76.8-97.8)
Delayed bathing until at least 1 hour after birth	94.3% (87.6-97.5)	96.7% (93.4-98.4)	97.9% (95.6-99.0)	98.1% (96.9-99.0)	96.5% (88.9-99.0)
Ties or clamps cord when pulsations stop or by 2-3 minutes after birth	92.6% (81.6-97.3)	92.8% (82.7-97.2)	91.4% (87.3-94.3)	92.8% (85.4-96.6)	92.7% (76.6-98.0)
Cuts cord with clean blade or scissors	99.7% (97.8-100)	99.7% (97.9-100)	98.8% (95.2-99.7)	99.7% (97.8-100)	99.4% (97.3-99.9)
Administers chlorhexidine to the newborn cord	Not measured	73.7% (46.0-90.2)	81.9% (54.6-94.5)	95.0% (88.8-97.8)	91.1% (78.4-96.6)
Breastfeeding initiated within the first hour	67.5% (41.8-85.7)	27.6% (13.1-49.2)	33.7% (18.1-54.0)	60.6% (39.9-78.2)	55.3% (38.0-71.4)
Check's baby's temperature within 15 minutes after birth	2.7% (0.4-15.2)	0%	0.6% (0.1-5.7)	1.9% (0.8-4.3)	5.4% (1.2-22.0)
Takes mother's vital signs 15 minutes after birth	0.3% (0-2.8)	1.8% (0.5-5.9)	1.8% (0.4-7.3)	6.2% (2.4-14.7)	4.5% (0.9-19.1)
Weighs the baby	Not measured	86.3% (57.2-96.7)	85.6% (63.1-95.4)	96.3% (89.8-98.7)	88.5% (45.4-98.6)
Mother and newborn kept in same room after delivery (rooming in)	98.3% (96.1-99.3)	96.7% (88.3-99.1)	95.7% (92.8-97.5)	98.9% (96.8-99.7)	99.7% (98.4-98.8)
Baby kept skin-to-skin with mother for first hour after birth	68.8% (40.1-87.9)	39.5% (20.0-63.0)	50.3% (29.4-71.1)	72.3% (59.6-82.3)	73.2% (49.0-88.6)
Provides tetracycline ointment prophylaxis	0%	0.3% (0-2.9)	0.9% (0.2-4.6)	10.4% (4.4-22.4)	4.8% (1.5-13.9)
Administers Vitamin K to newborn	0%	0.3% (0-2.1)	0%	0%	0%
Administers chlorhexidine to the newborn cord	0%	73.7% (46.2-90.1)	81.9% (54.8-94.4)	95.0% (88.8-97.8)	91.1% (78.5-96.6)
If mother identified as HIV positive, administers ARV to newborn	100%	75.0% (20.5-97.2)	0%	0%	25.0% (2.3-82.5)
Administers antibiotics to mother	1.0% (0.3-3.6)	1.2% (0.5-2.7)	0%	1.8% (0.9-3.5)	6.0% (1.1-27.0)

Appendix 2 - Supplementary material: objective 2

Table S1 Summary of search terms

Term	Concept	Search terms
1	Coverage	Clinical competence.mp.; OR Contact.mp.; Content coverage.mp.; OR Coverage.mp.; effective coverage.mp.; OR Health Facilities.mp.; OR Health Services Accessibility.mp.; OR Health Services Needs and Demand.mp.; OR high quality contact.mp.; OR input adjusted coverage.mp.; OR intervention coverage.mp.; OR Medical Audit.mp.; OR outcome adjusted coverage.mp.; OR Patient Acceptance of Health Care.mp.; OR Population level coverage.mp.; quality adjusted contact.mp.; OR quality adjusted coverage.mp.; OR quality adjusted measurement.mp.; OR quality along the continuum.mp.; OR Quality Assurance.mp.; OR quality cascade.mp.; OR quality contact.mp.; OR Quality improvement.mp.; OR Quality indicators.mp.; OR OR Quality of care.mp.; OR Quality of Health Care.mp.;
2	Bottleneck	adequate care.mp.; OR bottleneck.mp.; OR bottleneck analysis.mp.; OR bottleneck of implementation.mp.; OR gaps in coverage.mp.; OR implementation bottleneck.mp.; OR Tanahashi.mp.
3	Linking	linking household.mp.; OR linking household.mp. OR linking household survey and health facility.mp.; OR linking service.mp.
4	**Effective coverage**	**Term 1 OR Term 2 OR Term 3**
5	Child health intervention	care seeking.mp. ; OR childhood illness.mp. ; OR pneumonia.mp. ; OR diarrh*.mp. ; OR newborn illness.mp. ; OR health worker.mp. ; OR facility readiness.mp. ; OR intervention.mp. ; OR utilization.mp. ; OR access to care.mp. ; OR availability coverage.mp. ; OR health facilities.mp. ; OR accessibility coverage.mp. ; OR health facility.mp. ; OR HIV.mp. ; OR perinatal care.mp. ; OR postnatal care.mp. ; OR immunization.mp. ; OR immunisation.mp. ; OR treatment of sick children.mp. ; OR nutrition coverage.mp. ; OR newborn care.mp. ; OR breastfeeding.mp. ; OR infant feeding.mp. ; OR (maternal and child health intervention).mp. ; OR MCH intervention.mp. ; OR content intervention.mp. ; OR childhood immunization.mp. ; OR childhood vaccination.mp. ; OR missed opportunities.mp. ; OR malaria prevention.mp. ; OR malaria treatment.mp. ; OR health service delivery.mp. ; OR health service provision.mp. ; OR community health worker.mp. ; OR CHW.mp.
6	Newborn/child	Adolescent.mp.; OR baby.mp.; OR boy.mp.; OR child mortality.mp.; OR child*.mp.; OR child, preschool.mp.; OR exp adolescent/ or exp child/ or exp infant/; OR girl.mp.; OR infant.mp.; OR infant.mp., low birth weight.mp.; OR infant, newborn.mp.; OR infant, small for gestational

		age.mp.; OR neonatal.mp.; OR neonate.mp.; OR newborn.mp.; OR young infant.mp.
7	Childbirth	obstetric care.mp. ; OR obstetric services.mp. ; OR (maternal and newborn).mp.; OR (maternal and child).mp. ; OR RMNCH.mp. ; OR mnch.mp. ; OR mnh.mp. ; OR intrapartum.mp. ; OR peripartum.mp. ; OR labour.mp. ; OR labor.mp. ; OR facility delivery.mp. ; OR facility birth.mp. ; OR facility based birth.mp. ; OR institutional birth.mp. ; OR childbirth.mp. ; OR birth.mp. ; OR immediate newborn.mp.
8	Postnatal care	postpartum care.mp. ; OR Postpartum Period/; OR PPC.mp.
9	Child health	Breastfeeding.mp.; OR childhood illness.mp.; OR childhood immunizations.mp.; OR childhood vaccinations.mp.; OR diarrhea.mp.; OR HIV.mp.; OR Immunization/ immunisation.mp.; OR infant feeding.mp.; OR malaria prevention.mp.; OR malaria treatment.mp.; OR maternal and child health interventions.mp.; OR MCH Interventions.mp.; OR newborn care.mp.; OR newborn illness.mp.; OR nutrition.mp.; OR pneumonia.mp.; OR treatment of sick children.mp.;
10	**Target population/ intervention**	**Term 5 OR Term 6 OR Term 7 OR Term 8 OR Term 9**
11	Setting; LMIC	Developing Countries/; OR ((developing or less* developed or under developed or underdeveloped or middle income or low* income) adj (economy or economies)) .ti,ab. ; OR ((developing or less* developed or under developed or underdeveloped or middle income or low* income or underserved or under served or deprived or poor*) adj (countr* or nation? or population? or world.ti,ab.; OR (low* adj (gdp or gnp or gross domestic or gross national)) .ti,ab. ; OR (low adj3 middle adj3 countr*).ti,ab.; OR (lmic or lmics or third world or lami countr.ti,ab.; OR transitional countr.ti,ab.; OR global south.ti,ab.; OR Democratic People's Republic of Korea/; OR (North Korea or (Democratic People* Republic adj2 Korea)) .ti,ab.; OR Cambodia/; OR Cambodia.ti,ab. ; OR Indonesia/; OR (Indonesia or Dutch East Indies) .ti,ab. ; OR (Kiribati or Gilbert Islands or Phoenix Islands or Line Islands) .ti,ab.; OR Laos/; OR (Laos or (Lao adj1 Democratic Republic)) .ti,ab. ; OR Micronesia/; OR Micronesia.ti,ab.; OR Mongolia/; OR Mongolia.ti,ab. ; OR Myanmar/; OR (Myanmar or Burma).ti,ab.; OR Papua New Guinea/; OR (Papua New Guinea or German New Guinea or British New Guinea or Territory of Papua) .ti,ab. ; OR Philippines/; OR (Philippines or Philippine Islands) .ti,ab. ; OR Solomon Islands.ti,ab.; OR Timor-Leste/; OR (Timor-Leste or East Timor or Portuguese Timor) .ti,ab. ; OR Vanuatu/; OR (Vanuatu or New Hebrides) .ti,ab. ; OR Vietnam/; OR (Viet Nam or Vietnam or French Indochina) .ti,ab.; OR American Samoa/; OR American Samoa.ti,ab.; OR exp China/; OR China.ti,ab.; OR Fiji/; OR Fiji.ti,ab. ; OR Malaysia/; OR (Malaysia or Malayan Union or Malaya) .ti,ab. ; OR Marshall Islands.ti,ab.; OR Nauru.ti,ab.; OR Independent State of Samoa"/; OR ((Samoa not American Samoa) or Western Samoa or Navigator Islands or Samoan Islands) .ti,ab. ; OR Thailand/; OR (Thailand or Siam) .ti,ab. ; OR Tonga/; OR Tonga.ti,ab.; OR (Tuvalu or Ellice Islands) .ti,ab. ; OR Melanesia/; OR Melanesia.ti,ab.; OR Polynesia/; OR Polynesia.ti,ab.; OR Kyrgyzstan/; OR (Kyrgyzstan or Kyrgyz Republic or Kirghizia or Kirghiz) .ti,ab. ; OR Moldova/; OR Moldova.ti,ab.; OR Ukraine/; OR Ukraine.ti,ab; OR Uzbekistan/; OR Uzbekistan.ti,ab.; OR Albania/; OR Albania.ti,ab.; OR Armenia/ ; OR Armenia.ti,ab.; OR Azerbaijan/; OR Azerbaijan.ti,ab.; OR "Republic of Belarus"/; OR (Belarus or Byelarus or Byelorussia or Belorussia) .ti,ab.; OR Bosnia-Herzegovina/; OR (Bosnia or Herzegovina)

		.ti,ab. ; OR Bulgaria/ ; OR Bulgaria.ti,ab.; OR Georgia (Republic)" .ti,ab. ; OR Georgia.ti,ab. not Georgia/ ; OR Kazakhstan/; OR (Kazakhstan or Kazakh) .ti,ab. ; OR Kosovo/; OR Kosovo.ti,ab.; OR Montenegro/; OR Montenegro.ti,ab.; OR Republic of North Macedonia"/; OR North Macedonia.ti,ab.; OR Romania/; OR Romania.ti,ab.; OR exp Russia/; OR Russia (Pre-1917)"/ ; OR USSR/; OR (Russia or Russian Federation or USSR or Union of Soviet Socialist Republics or Soviet Union) .ti,ab. ; OR Serbia/; OR Serbia/; OR Turkey/; OR (Turkey.ti,ab. not animal/) or (Anatolia or Asia Minor) .ti,ab. ; OR Turkmenistan/; OR Turkmenistan.ti,ab.; OR Tajikistan/; OR Tajikistan.ti,ab.; OR Asia, Central/; OR Asia, Northern/; OR Central Asia.ti,ab.; OR Haiti/; OR (Haiti or Hayti) .ti,ab. ; OR Bolivia/; OR Bolivia.ti,ab.; OR El Salvador/; OR El Salvador.ti,ab.; OR Honduras/; OR Honduras.ti,ab.; OR Nicaragua/; OR Nicaragua.ti,ab.; OR Argentina/; OR (Argentina or Argentine Republic) .ti,ab. ; OR Belize/; OR (Belize or British Honduras) ; OR Brazil/; OR Brazil; OR Colombia/; OR Colombia.ti,ab.; OR Costa Rica/; OR Costa Rica.ti,ab.; OR Cuba/; OR Cuba.ti,ab.; OR Dominica/; OR Dominica.ti,ab.; OR Dominican Republic/ ; OR Dominican Republic.ti,ab.; OR Ecuador/; OR Ecuador.ti,ab.; OR Grenada/; OR Grenada.ti,ab.; OR Guatemala/; OR Guatemala.ti,ab.; OR Guyana/; OR (Guyana or British Guiana) .ti,ab. ; OR Jamaica/; OR Jamaica.ti,ab.; OR Mexico/; OR (Mexico or United Mexican States) .ti,ab. ; OR Paraguay/; OR Paraguay.ti,ab.; OR Peru/; OR Peru.ti,ab.; OR Saint Lucia/; OR (St Lucia or Saint Lucia or Iyonala or Hewanorra) .ti,ab. ; OR "Saint Vincent and the Grenadines"/; OR (Saint Vincent or St Vincent or Grenadines) .ti,ab. ; OR Suriname/; OR (Suriname or Dutch Guiana) .ti,ab. ; OR Venezuela/; OR Venezuela.ti,ab.; OR Djibouti/; OR (Djibouti or French Somaliland) .ti,ab. ; OR Egypt/; OR Egypt.ti,ab.; OR Morocco/; OR Morocco.ti,ab.; OR Tunisia/; OR Tunisia.ti,ab.; OR (Gaza or West Bank or Palestine) .ti,ab. ; OR Algeria/; OR Algeria.ti,ab.; OR Iran/; OR (Iran or Persia) .ti,ab. ; OR Iraq/; OR (Iraq or Mesopotamia) .ti,ab. ; OR Jordan/; OR Jordan.ti,ab.; OR Lebanon/; OR (Lebanon or Lebanese Republic) .ti,ab. ; OR Libya/; OR Libya.ti,ab.; OR Syria/; OR (Syria or Syrian Arab Republic) .ti,ab. ; OR Yemen/; OR Yemen.ti,ab.; OR Afghanistan/; OR Afghanistan.ti,ab.; OR Nepal/; OR Nepal.ti,ab.; OR Bangladesh/; OR Bangladesh.ti,ab.; OR Bhutan/; OR Bhutan.ti,ab.; OR exp India/; OR India.ti,ab.; OR Pakistan/; OR Pakistan.ti,ab.; OR Maldives.ti,ab.; OR Sri Lanka/; OR (Sri Lanka or Ceylon) ; OR Angola/; OR Angola.ti,ab.; OR Cameroon/; OR (Cameroon or Kamerun or Cameroun) .ti,ab. ; OR Cape Verde/; OR (Cape Verde or Cabo Verde) .ti,ab. ; OR Comoros/; OR (Comoros or Glorioso Islands or Mayotte) .ti,ab. ; OR Congo/; OR (Congo not ((Democratic Republic adj3 Congo) or congo red or crimean-congo)) .ti,ab. ; OR Cote d'Ivoire/; OR (Cote d'Ivoire or Cote dIvoire or Ivory Coast) .ti,ab. ; OR Eswatini/; OR (eSwatini or Swaziland) .ti,ab. ; OR Ghana/; OR (Ghana or Gold Coast) ; OR Kenya/; OR (Kenya or East Africa Protectorate) .ti,ab. ; OR Lesotho/; OR (Lesotho or Basutoland) .ti,ab. ; OR Mauritania/; OR Mauritania.ti,ab.; OR Nigeria/; OR Nigeria.ti,ab.; OR (Sao Tome adj2 Principe) ; OR Senegal/; OR Senegal.ti,ab.; OR Sudan/; OR (Sudan not South Sudan) .ti,ab. ; OR Zambia/; OR (Zambia or Northern Rhodesia) .ti,ab.; OR Zimbabwe/; OR (Zimbabwe or Southern Rhodesia) .ti,ab. ; OR Botswana/; OR (Botswana or Bechuanaland or Kalahari) .ti,ab. ; OR Equatorial Guinea/; OR (Equatorial Guinea or Spanish Guinea) .ti,ab. ; OR Gabon/; OR (Gabon or Gabonese Republic) .ti,ab. ; OR Mauritius/; OR (Mauritius or Agalega Islands) .ti,ab. ; OR Namibia/; OR (Namibia or German South West Africa) .ti,ab. ; OR South Africa/; OR (South Africa or Cape Colony or British Bechuanaland or Boer Republics or Zululand or Transvaal or Natalia Republic or Orange Free State) .ti,ab. ; OR Benin/; OR (Benin or Dahomey) Burkina Faso/ (Burkina Faso or Burkina Fasso or Upper Volta)

		.ti,ab. ; OR Burundi/; OR (Burundi or Ruanda-Urundi) .ti,ab. ; OR Central African Republic/; OR (Central African Republic or Ubangi-Shari) .ti,ab. ; OR Chad/; OR Chad.ti,ab.; OR Democratic Republic of the Congo.ti,ab.; OR (((Democratic Republic or DR) adj2 Congo) or Congo-Kinshasa or Belgian Congo or Zaire or Congo Free State) .ti,ab. ; OR Eritrea/; OR Eritrea.ti,ab.; OR Ethiopia/; OR (Ethiopia or Abyssinia) .ti,ab. ; OR Gambia/; OR Gambia; OR Guinea/; OR (Guinea not (New Guinea or Guinea Pig* or Guinea Fowl or Guinea-Bissau or Portuguese Guinea or Equatorial Guinea)) .ti,ab. ; OR Guinea-Bissau/; OR (Guinea-Bissau or Portuguese Guinea) .ti,ab. ; OR Liberia/; OR Liberia.ti,ab.; OR Madagascar/; OR (Madagascar or Malagasy Republic) .ti,ab.; OR Malawi/; OR (Malawi or Nyasaland) .ti,ab. ; OR Mali/; OR Mali.ti,ab.; OR Mozambique/; OR (Mozambique or Mocambique or Portuguese East Africa) .ti,ab. ; OR Niger/; OR (Niger not (Aspergillus or Peptococcus or Schizothorax or Cruciferae or Gobius or Lasius or Agelastes or Melanosuchus or radish or Parastromateus or Orius or Apergillus or Parastromateus or Stomoxys)) .ti,ab. ; OR Rwanda/; OR (Rwanda or Ruanda) .ti,ab. ; OR Sierra Leone/; OR (Sierra Leone or Salone) .ti,ab.; OR Somalia/; OR (Somalia or Somaliland) .ti,ab.; OR South Sudan/; OR South Sudan.ti,ab.; OR Tanzania/; OR (Tanzania or Tanganyika or Zanzibar) .ti,ab. ; OR Togo/; OR (Togo or Togolese Republic or Togoland) .ti,ab.; OR Uganda/; OR Uganda.ti,ab.; OR "africa south of the sahara"/; OR africa, central/; OR africa, eastern/; OR africa, southern/; OR africa, western/; OR ("Africa South of the Sahara" or sub-Saharan Africa or subSaharan Africa) .ti,ab. ; OR Central Africa.ti,ab.; OR Eastern Africa.ti,ab.; OR Southern Africa.ti,ab.; OR Western Africa.ti,ab.
11	**Final search**	**Term 4 AND Term 10 AND Term 11**

Table S2 Studies excluded at full-text review stage and reasons for exclusion

Reference	Reason for exclusion
Aaron G. et al. (2016) "Household coverage of fortified staple food commodities in Rajasthan, India." Plos One 2016;11:e0163176.	Population in need not relevant
Aaron, G et al. (2017). "Coverage of large-scale food fortification of edible oil, wheat flour, and maize flour varies greatly by vehicle and country but is consistently lower among the most vulnerable: results from coverage surveys in 8 countries J Nutr 2017;147:984S–94.	Population in need not relevant
Abd El Razik, M. S. and Salem, M.R. (2019). "From public health and demographic research to decision making: An intervention study in Giza Governorate-Egypt." Evaluation and Program Planning 77: 101704.	Outcome not a population level measure: denominator not population in need
Afolabi, R.F., et al. (2021) "Ethnicity as a cultural factor influencing complete vaccination among children aged 12-23 months in Nigeria." Human Vaccines & Immunotherapeutics 17(7): 2008.	No adjustment for quality of care
Aina, M., et al. (2017). "Preliminary results from direct-to-facility vaccine deliveries in Kano, Nigeria." Vaccine 35(17): 2175-2182.	Outcome not a population level measure: denominator not population in need
Akech, S., et al. (2019). "Magnitude and pattern of improvement in processes of care for hospitalised children with diarrhoea and dehydration in Kenyan hospitals participating in a clinical network." Tropical Medicine & International Health 24(1): 73-80.	Outcome not a population level measure: denominator not population in need
Alfiah, E., et al. (2019). "Coverage and adherence of weekly iron folic acid supplementation among school going adolescent girls in Indonesia." Annals of Nutrition and Metabolism 75 (3): 324.	Population in need not relevant
Allan, S., et al. (2021) "Inequities in childhood immunisation coverage associated with socioeconomic, geographic, maternal, child, and place of birth characteristics in Kenya." BMC Infectious Diseases 21:553.	No adjustment for quality of care
Allen, S. M., et al. (2017). "Measuring facility capability to provide routine and emergency childbirth care to mothers and newborns: An appeal to adjust for delivery caseload of facilities." PLoS ONE [Electronic Resource] 12(10): e0186515.	Outcome not a population level measure: denominator not population in need
Ampadu, H. H., et al. (2019). "Prescribing patterns and compliance with World Health Organization recommendations for the management of severe malaria: a modified cohort event monitoring study in public health facilities in Ghana and Uganda." Malaria Journal 18(1): 36.	Outcome not a population level measure: denominator not population in need
Ansari, N., et al. (2020). "Quality of care in prevention, detection and management of postpartum hemorrhage in hospitals in Afghanistan: an observational assessment." BMC Health Services Research 20(1): 484.	Relevance
Arsenault, C., et al. (2021) "Patient volume and quality of primary care in Ethiopia: findings from the routine health information system and the 2014 Service Provision Assessment survey." BMC Health Services Research 21:485.	Outcome not a population level measure: denominator not population in need
Ayieko, P., et al. (2019). "Effect of enhancing audit and feedback on uptake of childhood pneumonia treatment policy in hospitals that are part of a clinical network: a cluster randomized trial." Implementation Science 14(1): 20.	Outcome not a population level measure: denominator not population in need
Benzaken, C. L., et al. (2020). "Development of a cumulative metric of vaccination adherence behavior and its application among a cohort of 12-month-olds in western Kenya." Vaccine 38(18): 3429-3435.	No adjustment for quality of care
Bhattacharya, A. A., et al. (2019). "Monitoring childbirth care in primary health facilities: a validity study in Gombe State, northeastern Nigeria." Journal of Global Health 9(2): 020411.	Study type
Bhura, M., et al. (2020). "Evaluating implementation of "management of Possible Serious Bacterial Infection (PSBI) when referral is not feasible" in primary health care facilities in Sindh province, Pakistan." PLoS ONE [Electronic Resource] 15(10): e0240688.	Outcome not a population level measure: denominator not population in need
Biset, G., et al. (2021) "Full immunization coverage and associated factors among children age 12-23 months in Ethiopia: systematic	Study type

Reference	Reason for exclusion
review and meta-analysis of observational studies." Human Vaccines & Immunotherapeutics 17 (7): 2326.	
Brenner, S., et al. (2017). "Implementation research to improve quality of maternal and newborn health care, Malawi." Bulletin of the World Health Organization 95(7): 491-502.	Outcome not a population level measure: denominator not population in need
Buchmann, E. J. (2020). "Quality and readiness for facility-based childbirth in sub-Saharan Africa." BJOG: An International Journal of Obstetrics & Gynaecology 127(12): 1547.	Study type
Budu, E. et al. (2021). "Maternal healthcare utilization and full immunization coverage among 12–23 months children in Benin: a cross sectional study using population-based data." Archives of Public Health 79:34.	No adjustment for quality of care
Burke, D. (2018). "Advanced distribution of misoprostol for prevention of postpartum hemorrhage at home births in Haiti." International Journal of Gynecology and Obstetrics 143 (Supplement 3): 461.	Relevance
Carter, E. D., et al. (2018). "An agent-based model of effective coverage of appropriate management of child illness." American Journal of Tropical Medicine and Hygiene 99 (4 Supplement): 254.	Outcome not a population level measure: denominator not population in need
Carvajal-Aguirre, L., et al. (2017). "Does health facility service environment matter for the receipt of essential newborn care? Linking health facility and household survey data in Malawi." Journal of Global Health 7(2): 020508.	Outcome not a population level measure: denominator not population in need
Choi, S., et al. (2020). "Improved care and survival in severe malnutrition through eLearning." Archives of Disease in Childhood 105(1): 32-39.	Relevance
Cohen, J. L., et al. (2020). "Quality of clinical management of children diagnosed with malaria: A cross-sectional assessment in 9 sub-Saharan African countries between 2007-2018." PLoS Medicine / Public Library of Science 17(9): e1003254.	Outcome not a population level measure: denominator not population in need
Colson, K., et al. (2013). "Comparative estimates of immunisation coverage from three different sources: results from the SM2015 evaluation. Lancet. 2013;381:S32.	Results presented in another article
Colson, K., et al. (2015). "Comparative Estimates of Crude and Effective Coverage of Measles Immunization in Low-Resource Settings-Findings from Salud Mesoamérica 2015." PLoS ONE 10(7): e0130697	Outcome not a population level measure: denominator not population in need
Daka, D. W., et al. (2020). "Quality of clinical assessment and management of sick children by Health Extension Workers in four regions of Ethiopia: A cross-sectional survey." PLoS ONE [Electronic Resource] 15(9): e0239361.	Outcome not a population level measure: denominator not population in need
Das, M. K., et al. (2019). "Impact of Neonatal Resuscitation Capacity Building of Birth Attendants on Stillbirth Rate at Public Health Facilities in Uttar Pradesh, India." Indian pediatrics 56(5): 369-373.	Outcome not a population level measure: denominator not population in need
Day, L. et al. (2021). "Assessment of the validity of the measurement of newborn and maternal health-care coverage in hospitals (EN-BIRTH): an observational study." Lancet Global Health 9: e267.	Outcome not a population level measure: denominator not population in need
Deming, M.S., et al. (2002) "Tetanus toxoid coverage as an indicator of serological protection against neonatal tetanus"". Bull World Health Organ 2002;80:696–703.	Population in need not relevant
Eboreime, E. A., et al. (2019). "Effectiveness of the Diagnose-Intervene- Verify-Adjust (DIVA) model for integrated primary healthcare planning and performance improvement: an embedded mixed methods evaluation in Kaduna state, Nigeria." BMJ Open 9(3): e026016.	Outcome not a population level measure: denominator not population in need
Eboreime, E. A., et al. (2019). "Primary healthcare planning, bottleneck analysis and performance improvement: An evaluation of processes and outcomes in a Nigerian context." Evaluation & Program Planning 77: 101712.	Outcome not a population level measure: denominator not population in need

Reference	Reason for exclusion
Engle-Stone, R. et al. (2015). "Estimating the effective coverage of programs to control vitamin a deficiency and its consequences among women and young children in Cameroon. Food Nutr Bull. 2015;36(3 Suppl):S149–71.	Study type
Ezran, C., et al. (2019). "Assessing trends in the content of maternal and child care following a health system strengthening initiative in rural Madagascar: A longitudinal cohort study." PLoS Medicine 16 (8): (no pagination)(e1002869).	Relevance
Fink, G., et al. (2020). "Antibiotic exposure among children younger than 5 years in low-income and middle-income countries: a cross-sectional study of nationally representative facility-based and household-based surveys." The Lancet Infectious Diseases 20(2): 179-187.	Intervention type
Fisseha, G., et al. (2019). "Quality of intrapartum and newborn care in Tigray, Northern Ethiopia." BMC Pregnancy & Childbirth 19(1): 37.	Outcome not a population level measure: denominator not population in need
Francetic, I., et al. (2019). "Going operational with health systems governance: supervision and incentives to health workers for increased quality of care in Tanzania." Health Policy & Planning 34(Supplement_2): ii77-ii92.	Outcome not a population level measure: denominator not population in need
Fullman, N., et al. (2017). "Measuring progress and projecting attainment on the basis of past trends of the health-related Sustainable Development Goals in 188 countries: an analysis from the Global Burden of Disease Study 2016." The Lancet 390(10100): 1423-1459.	No adjustment for quality of care
Gage, A. D., et al. (2018). "Does quality influence utilization of primary health care? Evidence from Haiti." Global Health 14(1): 59.	Relevance
Gakidou, E., et al. (2006). "Assessing the effect of the 2001–06 Mexican health reform: an interim report card. Lancet (London, England). 2006; 368(9550):1920–35.	No adjustment for quality of care
Galstyan, S. H., et al. (2019). "Cross-sectional study of the quality of neonatal care services in Armenia." International journal of health care quality assurance 32(8): 1145-1161.	Outcome not a population level measure: denominator not population in need
Getachew, T., et al. (2020). "Assessing the quality of care in sick child services at health facilities in Ethiopia." BMC Health Services Research 20(1): 574.	Outcome not a population level measure: denominator not population in need
Goleman, M. J., et al. (2018). "Quality Improvement Initiative to Improve Human Papillomavirus Vaccine Initiation at 9 Years of Age." Academic Pediatrics 18(7): 769-775.	Setting: Columbus, Ohio (USA)
Guzha, B. T., et al. (2018). "Assessment of quality of obstetric care in Zimbabwe using the standard primipara." BMC Pregnancy & Childbirth 18(1): 205.	Outcome not a population level measure: denominator not population in need
Habte, A. et al. (2021). "Determinants of practice of preconception care among women of reproductive age group in southern Ethiopia, 2020: content analysis." Reproductive Health 18:100.	Intervention type
Hayford (2013) Measles vaccination coverage estimates from surveys, clinic records, and immune markers in oral fluid and blood: a population-based cross-sectional study	Outcome not a population level measure: denominator not population in need
Horwood, C., et al. (2017). "A continuous quality improvement intervention to improve the effectiveness of community health workers providing care to mothers and children: a cluster randomised controlled trial in South Africa." Human Resources for Health [Electronic Resource] 15(1): 39.	No adjustment for quality of care
Huybregts, L., et al. (2019). "Impact on child acute malnutrition of integrating small-quantity lipid-based nutrient supplements into community-level screening for acute malnutrition: A cluster-randomized controlled trial in Mali." PLoS Medicine / Public Library of Science 16(8): e1002892.	No adjustment for quality of care
Idzerda, L. (2011). Access to primary healthcare services for the Roma population in Serbia: a secondary data analysis. BMC Int Health Human Rights. 2011;11:10.	No adjustment for quality of care
Kamath, A. M., et al. (2020). "Assessing multidimensional care coverage for pre-eclampsia in the era of universal health coverage: A pre-post evaluation of the Salud Mesoamerica Initiative." International Journal of Gynaecology & Obstetrics 149(3): 318-325.	Intervention type

Reference	Reason for exclusion
Kanyangarara, M. and V. B. Chou (2017). "Linking household surveys and health facility assessments to estimate intervention coverage for the Lives Saved Tool (LiST)." BMC Public Health 17(Suppl 4): 780.	Intervention type
Karim, A., et al. (2020). "A systems approach to assessing complexity in health interventions: an effectiveness decay model for integrated community case management." Global health action 13(1).	Study type
Kc, A., et al. (2020). "Quality of Care for Maternal and Newborn Health in Health Facilities in Nepal." Maternal & Child Health Journal 24(Suppl 1): 31-38.	Outcome not a population level measure: denominator not population in need
Khan, Z., et al. (2000) Coverage and Efficacy of Measles Immunization in Rural Areas of Aligarh	Outcome not a population level measure: denominator not population in need
Khumalo, P. N., et al. (2020). "The Cascade of Care From Routine Point-of-Care HIV Testing at Birth: Results From an 18-Months Pilot Program in Eswatini." Journal of Acquired Immune Deficiency Syndromes (1999) 84(Supplement 1): S22-S27.	Outcome not a population level measure: denominator not population in need
Kim, S. S., et al. (2019). "Behavior Change Interventions Delivered through Interpersonal Communication, Agricultural Activities, Community Mobilization, and Mass Media Increase Complementary Feeding Practices and Reduce Child Stunting in Ethiopia." Journal of Nutrition 149(8): 1470-1481.	No adjustment for quality of care
Klootwijk, L., et al. (2019). "Challenges affecting prompt access to adequate uncomplicated malaria case management in children in rural primary health facilities in Chikhwawa Malawi." BMC Health Services Research 19(1): 735.	No adjustment for quality of care
Koulidiati, J. L., et al. (2018). "Factors associated with effective coverage of child health services in Burkina Faso." Tropical Medicine & International Health 23(11): 1188-1199.	Duplicate
Koulidiati, J. L., et al. (2018). "Measuring effective coverage of curative child health services in rural Burkina Faso: a cross-sectional study." BMJ Open 8(5): e020423.	Duplicate
Koulidiati, J-L. et al. (2021). "Impact of Performance-Based Financing on effective coverage for curative child health services in Burkina Faso: Evidence from a quasi-experimental design" Tropical Medicine and International Health 8:1002.	Results presented in another article
Kruk, M. E., et al. (2017). "Variation in quality of primary-care services in Kenya, Malawi, Namibia, Rwanda, Senegal, Uganda and the United Republic of Tanzania." Bulletin of the World Health Organization 95(6): 408-418.	Outcome not a population level measure: denominator not population in need
Kruk, M. E., et al. (2018). "Content of Care in 15,000 Sick Child Consultations in Nine Lower-Income Countries." Health Services Research 53(4): 2084-2098.	Outcome not a population level measure: denominator not population in need
Lama, T. P., et al. (2020). "Assessment of facility and health worker readiness to provide quality antenatal, intrapartum and postpartum care in rural Southern Nepal." BMC Health Services Research 20(1): 16.	Outcome not a population level measure: denominator not population in need
Langston, A., et al. (2019). "Testing a simplified tool and training package to improve integrated Community Case Management in Tanganyika Province, Democratic Republic of Congo: a quasi-experimental study." Journal of Global Health 9(1): 010810.	Outcome not a population level measure: denominator not population in need
Lansky, S., et al. (2018). "Monitoring care during childbirth to reduce maternal and infant mortality in Belo Horizonte, Brazil." International Journal of Gynecology and Obstetrics 143 (Supplement 3): 494-495.	Not retrieved
Larson, E., et al. (2019). "Effect of a maternal and newborn health system quality improvement project on the use of facilities for childbirth: a cluster-randomised study in rural Tanzania." Tropical Medicine & International Health 24(5): 636-646.	No adjustment for quality of care
Lauria, M. E., et al. (2019). "Assessing the Integrated Community-Based Health Systems Strengthening initiative in northern Togo: a pragmatic effectiveness-implementation study protocol." Implementation Science 14(1): 92.	Study type

Reference	Reason for exclusion
Lazzerini, M., et al. (2017). "Improving the quality of hospital care for children by supportive supervision: a cluster randomized trial, Kyrgyzstan." Bulletin of the World Health Organization 95(6): 397-407.	Relevance
Lazzerini, M., et al. (2019). "Nutritional services for children in Beira, Mozambique: a study reporting on participatory use of data to generate quality improvement recommendations." BMJ open quality 8(4): e000758.	Outcome not a population level measure: denominator not population in need
Lee, J., et al. (2017). "Strategy for integrated linkages between service delivery and household utilization across programs." Annals of Nutrition and Metabolism 71 (Supplement 2): 115.	Study type
Leslie, H. H., et al. (2017). "Association between infrastructure and observed quality of care in 4 healthcare services: A cross-sectional study of 4,300 facilities in 8 countries." PLoS Medicine / Public Library of Science 14(12): e1002464.	Outcome not a population level measure: denominator not population in need
Leyvraz, M., et al. (2017). "Coverage of nutrition interventions intended for infants and young children varies greatly across programs: Results from coverage surveys in 5 countries." Journal of Nutrition 147(5): 995S-1003S.	Results presented in another article
Lozano, R., et al. (2006). "Benchmarking of performance of Mexican states with effective coverage. Lancet 2006;368:1729–41.	Population in need not relevant
Lozano, R., et al. (2020). "Measuring universal health coverage based on an index of effective coverage of health services in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019." The Lancet 396(10258): 1250-1284.	Study type
Luo, H., et al. (2016). Predicted effects of current and potential micronutrient intervention programs on adequacy of folate and vitamin B-12 intake in a national sample of women and young children in Cameroon. FASEB J. 2016;30((Luo H.; Stewart C.P.; Brown K.H.; Engle-Stone R.) Program in International and Community Nutrition, University of California, Davis, United States).	Population in need not relevant
Manyazewal, T., et al. (2018). "Improving immunization capacity in Ethiopia through continuous quality improvement interventions: a prospective quasi-experimental study." Infectious Diseases of Poverty 7(1): 119.	Relevance
Martinez, S. et al., (2011). "Effective coverage of health interventions in Latin America and the Caribbean: metrics for the assessment of health systems performance. Salud Publica Mex. 2011;53(SUPPL. 2):S78–84	Not in English
Maves, K., et al. (2020). "Rapid baseline assessment of peripartum care delivery by skilled birth attendants in rural India." Journal of Investigative Medicine 68 (1): A39.	Outcome not a population level measure: denominator not population in need
McGuire, F., et al. (2021). " The effect of distance on maternal institutional delivery choice: Evidence from Malawi." Health Economics 1:24.	Outcome not a population level measure: denominator not population in need
Minta, A. A., et al. (2020). "Seroprevalence of Measles, Rubella, Tetanus, and Diphtheria Antibodies among Children in Haiti, 2017." American Journal of Tropical Medicine & Hygiene 103(4): 1717-1725.	Outcome not a population level measure: denominator not population in need
Minta, A. et al. (2021). "Hepatitis B surface antigen seroprevalence among children in the Philippines, 2018." Vaccine 39: 1982.	No adjustment for quality of care
Morof, D., et al. (2019). "Addressing the Third Delay in Saving Mothers, Giving Life Districts in Uganda and Zambia: Ensuring Adequate and Appropriate Facility-Based Maternal and Perinatal Health Care." Global Health Science & Practice 7(Suppl 1): S85-S103.	Outcome not a population level measure: denominator not population in need
Mothupi, M. C., et al. (2018). "Measurement approaches in continuum of care for maternal health: a critical interpretive synthesis of evidence from LMICs and its implications for the South African context." BMC Health Services Research 18(1): 539.	Study type
Mukamurigo, J., et al. (2019). "Quality of intrapartum care for healthy women with spontaneous onset of labour in Rwanda: A health facility-based, cross-sectional study." Sexual & reproductive	Outcome not a population level measure: denominator not population in need

Reference	Reason for exclusion
healthcare : official journal of the Swedish Association of Midwives 19: 78-83.	
Munabi-Babigumira, S., et al. (2019). "Implementing the skilled birth attendance strategy in Uganda: a policy analysis." BMC Health Services Research 19(1): 655.	Study type
Munos, M. K., et al. (2017). "Improving coverage measurement for reproductive, maternal, neonatal and child health: gaps and opportunities." Journal of Global Health 7(1): 010801.	Study type
Mutua, M., et al. (2021). "Inequities in On-Time Childhood Vaccination: Evidence From Sub-Saharan Africa." Americal Journal of Preventive Medicine 60(1S1):S11.	No adjustment for quality of care
Mwapasa, V., et al. (2017). "Impact of Mother-Infant Pair Clinics and Short-Text Messaging Service (SMS) Reminders on Retention of HIV-Infected Women and HIV-Exposed Infants in eMTCT Care in Malawi: A Cluster Randomized Trial." Journal of Acquired Immune Deficiency Syndromes: JAIDS 75 Suppl 2: S123-S131.	Outcome not a population level measure: denominator not population in need
Mwita, S. K., et al. (2019). "Engagement of National Stakeholders and Communities on Health-Care Quality Improvement: Experience from the Implementation of the Partnership for HIV-Free Survival in Tanzania." Journal of the International Association of Providers of AIDS Care 18: 2325958219847454.	Outcome not a population level measure: denominator not population in need
Nagar, R., et al. (2018). "A cluster randomized trial to determine the effectiveness of a novel, digital pendant and voice reminder platform on increasing infant immunization adherence in rural Udaipur, India." Vaccine 36(44): 6567-6577.	Outcome not a population level measure: denominator not population in need
Nanthavong (2015) Diphtheria in Lao PDR: Insufficient Coverage or Ineffective Vaccine?	Outcome not a population level measure: denominator not population in need
Ngoma, T., et al. (2019). "Addressing the Second Delay in Saving Mothers, Giving Life Districts in Uganda and Zambia: Reaching Appropriate Maternal Care in a Timely Manner." Global Health Science & Practice 7(Suppl 1): S68-S84.	Outcome not a population level measure: denominator not population in need
Nguyen, P. H., et al. (2018). "Importance of coverage and quality for impact of nutrition interventions delivered through an existing health programme in Bangladesh." Maternal & Child Nutrition 14(4): e12613.	Relevance
Nguyen, P., et al. (2020). "Quality-Adjusted Coverage of Nutrition Interventions Across the Continuum of Care: Insights from Household and Health Facility Data in Bangladesh." Current Developments in Nutrition 4(Suppl 2): 254-254.	Abstract, insufficient data
Nikiema (2017) Effectiveness of facility-based personalized maternal nutrition counseling in improving child growth and morbidity up to 18 months: A cluster-randomized controlled trial in	Relevance
Odjidja, E. N., et al. (2019). "Delivery of integrated infectious disease control services under the new antenatal care guidelines: a service availability and readiness assessment of health facilities in Tanzania." BMC Health Services Research 19(1): 153.	Outcome not a population level measure: denominator not population in need
Ojha, C. R., et al. (2017). "Impact of mass drug administration for elimination of lymphatic filariasis in Nepal." PLoS Neglected Tropical Diseases [electronic resource] 11(7): e0005788.	Relevance
Okawa, S., et al. (2019). "Effect of continuum-of-care intervention package on improving contacts and quality of maternal and newborn healthcare in Ghana: A cluster randomised controlled trial." BMJ Open 9 (9) (no pagination)(e025347).	Outcome not a population level measure: denominator not population in need
Oresanya, O., et al. (2019). "Effect of community-based intervention on improving access to treatment for sick under-five children in hard-to-reach communities in Niger State, Nigeria." Journal of Global Health 9(1): 010803.	No adjustment for quality of care
Owili, P. O., et al. (2017). "Quality of maternity care and its determinants along the continuum in Kenya: A structural equation modeling analysis." PLoS ONE [Electronic Resource] 12(5): e0177756	Outcome not a population level measure: denominator not population in need
Page-Shipp, L., et al. (2018). "Household point of care CD4 testing and isoniazid preventive therapy initiation in a household TB	Intervention type

Reference	Reason for exclusion
contact tracing programme in two districts of South Africa." PLoS ONE [Electronic Resource] 13(3): e0192089.	
Pallangyo, E., et al. (2017). "Improved postpartum care after a participatory facilitation intervention in Dar es Salaam, Tanzania: a mixed method evaluation." Glob Health Action 10(1): 1295697.	Outcome not a population level measure: denominator not population in need
Pugliese-Garcia, M., et al. (2020). "Childbirth care in Egypt: a repeat cross-sectional analysis using Demographic and Health Surveys between 1995 and 2014 examining use of care, provider mix and immediate postpartum care content." BMC Pregnancy & Childbirth 20(1): 46.	Outcome not a population level measure: denominator not population in need
Qazi, U., et al. (2019). "Compliance to timely vaccination in an Expanded Program on Immunization center of Pakistan." Vaccine 37(32): 4618-4622.	Outcome not a population level measure: denominator not population in need
Rajbhandari, S. P., et al. (2017). "Postpartum hemorrhage prevention in Nepal: a program assessment." BMC Pregnancy & Childbirth 17(1): 169.	Relevance
Ram, P. K., et al. (2017). "Coverage gaps in early initiation of breastfeeding among newborns, sub-saharan Africa, 2010-2015." American Journal of Tropical Medicine and Hygiene 97 (5 Supplement 1): 285.	Abstract, insufficient data
Randive, B.B., (2013). Effective coverage of institutional deliveries under the Janani Suraksha Yojana programme in high maternal mortality provinces of India: analysis of data from an annual health survey. Lancet. 2013;381:S32.	Abstract, insufficient data
Razavi-Shearer, D., et al. (2018). "Global prevalence, treatment, and prevention of hepatitis B virus infection in 2016: a modelling study." The Lancet Gastroenterology & Hepatology 3(6): 383-403	Relevance
Rivera, D., et al. (2017). "Integrated community case management (iCCM) of childhood infection saves lives in hard-to-reach communities in Nicaragua." Pan American Journal of Public Health 41: e66	Outcome not a population level measure: denominator not population in need
Rogers, E., et al. (2018). "Quality of care of treatment for uncomplicated severe acute malnutrition provided by lady health workers in Pakistan." Public Health Nutrition 21(2): 385-390.	Outcome not a population level measure: denominator not population in need
Saaka, M., et al. (2018). "Prevalence and determinants of essential newborn care practices in the Lawra District of Ghana." BMC Pediatrics 18(1): 173.	No adjustment for quality of care
Sally, E. T. and E. Kenu (2017). "Evaluation of access and utilization of EPI services amongst children 12-23 months in Kwahu Afram Plains, Eastern region, Ghana." The Pan African medical journal 28: 238.	No adjustment for quality of care
Sami, S., et al. (2018). "Understanding health systems to improve community and facility level newborn care among displaced populations in South Sudan: a mixed methods case study." BMC Pregnancy & Childbirth 18(1): 325	Outcome not a population level measure: denominator not population in need
Sanjel, K., et al. (2019). "Patterns and determinants of essential neonatal care utilization among underprivileged ethnic groups in Midwest Nepal: a mixed method study." BMC Pregnancy & Childbirth 19(1): 310.	Relevance
Semrau, K. E. A., et al. (2017). "Outcomes of a Coaching-Based WHO Safe Childbirth Checklist Program in India." New England Journal of Medicine 377(24): 2313-2324.	Outcome not a population level measure: denominator not population in need
Serván-Mori, E., et al. (2019). "Improving the effective maternal-child health care coverage through synergies between supply and demand-side interventions: Evidence from Mexico." Journal of Global Health 9(2).	Intervention type
Sharma, J., et al. (2018). "Can India's primary care facilities deliver? A cross-sectional assessment of the Indian public health system's capacity for basic delivery and newborn services." BMJ Open 8(6): e020532.	Outcome not a population level measure: denominator not population in need
Sheffel, A., et al. (2019). "Methods for analysis of complex survey data: an application using the Tanzanian 2015 Demographic and Health Survey and Service Provision Assessment." Journal of Global Health 9(2): 020902.	Intervention type

Reference	Reason for exclusion
Sindelar, K., et al. (2020). "Beyond the facility: An evaluation of seven community-based pediatric HIV testing strategies and linkage to care outcomes in a high prevalence, resource-limited setting." PLoS ONE [Electronic Resource] 15(9): e0236985.	Outcome not a population level measure: denominator not population in need
Sitrin, D., et al. (2017). "Evidence from household surveys for measuring coverage of newborn care practices." Journal of Global Health 7(2): 020503.	Outcome not a population level measure: denominator not population in need
Soremekun, S., et al. (2018). "Variation in the quality and out-of-pocket cost of treatment for childhood malaria, diarrhoea, and pneumonia: Community and facility based care in rural Uganda." PLoS ONE [Electronic Resource] 13(11): e0200543.	Relevance
Tang, X., et al. (2017). "Timeliness and completeness of measles vaccination among children in rural areas of Guangxi, China: A stratified three-stage cluster survey." Journal of Epidemiology 27: 317e324.	No adjustment for quality of care
Tariku, A., et al. (2020). "Prevention and treatment of suspected pneumonia in Ethiopian children less than five years from household to primary care." Acta Paediatrica, International Journal of Paediatrics.	Relevance
Taylor, C., et al. (2019). "Examination of malaria service utilization and service provision: an analysis of DHS and SPA data from Malawi, Senegal, and Tanzania." Malaria Journal 18(1): 258.	Relevance
Teasdale, C. A., et al. (2017). "High risk of loss to follow-up among South African children on ART during transfer, a retrospective cohort analysis with community tracing." Journal of the International AIDS Society 20(1): 21748.	Outcome not a population level measure: denominator not population in need
Thapa Pachya, A., et al. (2020). "Newborn Service Readiness of Primary Level Health Facilities of Eastern Mountain Region of Nepal." Journal of Nepal Health Research Council 17(4): 431-436.	Outcome not a population level measure: denominator not population in need
Thiam, S., et al. (2019). "Knowledge and practices of mothers and caregivers on diarrhoeal management among under 5-year-old children in a medium-size town of Senegal." Acta Tropica 194: 155-164.	No adjustment for quality of care
Tippins, A., et al. (2017). "Timeliness of childhood vaccination in the Federated States of Micronesia." Vaccine 35: 6404.	No adjustment for quality of care
Tomlin, K., et al. (2020). "Assessing capacity of health facilities to provide routine maternal and newborn care in low-income settings: what proportions are ready to provide good-quality care, and what proportions of women receive it?" BMC Pregnancy & Childbirth 20(1): 289.	Outcome not a population level measure: denominator not population in need
Travassos (2016) Immunization Coverage Surveys and Linked Biomarker Serosurveys in Three Regions in Ethiopia	Outcome not a population level measure: denominator not population in need
Tripura, R., et al. (2018). "A Controlled Trial of Mass Drug Administration to Interrupt Transmission of Multidrug-Resistant Falciparum Malaria in Cambodian Villages." Clinical Infectious Diseases 67(6): 817-826.	Relevance
Tumilowicz, A., et al. (2019). "Bottlenecks and predictors of coverage and adherence outcomes for a micronutrient powder program in Ethiopia." Maternal & Child Nutrition 15(S5): e12807.	No adjustment for quality of care
Tumilowicz, A., et al. (2019). "Mixed methods evaluation explains bypassing of vouchers in micronutrient powder trial in Mozambique." Maternal & Child Nutrition 15(S5): e12718.	No adjustment for quality of care
Ugwa, E., et al. (2018). "Use of maternal and newborn data for decision making by health workers in Ebonyi and Kogi, Nigeria." International Journal of Gynecology and Obstetrics 143 (Supplement 3): 508-509.	Intervention type
van den Ent, M. M. V. X., et al. (2017). "Equity and immunization supply chain in Madagascar." Vaccine 35(17): 2148-2154.	Study type
Wang, W., et al. (2017). "Limited Service Availability, Readiness, and Use of Facility-Based Delivery Care in Haiti: A Study Linking Health Facility Data and Population Data." Global health, science and practice 5(2): 244-260.	Results presented in later article

Reference	Reason for exclusion
Wangdi, K., et ai. (2014). "Prevalence of asymptomatic malaria and bed net ownership and use in Bhutan, 2013: a country earmarked for malaria elimination." Malar J 2014;13.	No adjustment for quality of care
Wanzira, H., et al. (2018). "Quality of care for children with acute malnutrition at health center level in Uganda: a cross sectional study in West Nile region during the refugee crisis." BMC Health Services Research 18(1): 561.	Relevance
Wehrmeister, F. C., et al. (2020). "Wealth-related inequalities in the coverage of reproductive, maternal, newborn and child health interventions in 36 countries in the African Region." Bulletin of the World Health Organization 98(6): 394-405.	No adjustment for quality of care
Wiens, K. E., et al. (2019). "Geographic variation in oral rehydration therapy coverage in low-and middle-income countries, 2000-2017." American Journal of Tropical Medicine and Hygiene 101 (5 Supplement): 399.	No adjustment for quality of care
Wilson, N. (2019). "At-scale evidence from 26 national household surveys on the prevention of mother-to-child transmission of HIV cascade." Health Policy & Planning 34(7): 514-519.	No adjustment for quality of care
Wiradnyani, L. A. A., et al. (2019). "Behind the low and high coverage of vitamin a supplementation program among children 6-59 months in six provinces of Indonesia." Annals of Nutrition and Metabolism 75 (3): 392.	Abstract, insufficient data
Woldeamanuel, B. T. (2020). "Trends and factors associated to early initiation of breastfeeding, exclusive breastfeeding and duration of breastfeeding in Ethiopia: evidence from the Ethiopia Demographic and Health Survey 2016." International Breastfeeding Journal 15(1): 3.	No adjustment for quality of care
Xu, W.-b., et al. (2020). "Investigation and analysis of antibody levels of hepatitis A among children before and after implementing the Expanded National Immunization Program in China." Vaccine 38(4): 878-881.	Outcome not a population level measure: denominator not population in need
Yan, L. D., et al. (2018). "Equity dimensions of the availability and quality of reproductive, maternal and neonatal health services in Zambia." Tropical Medicine & International Health 23(4): 433-445.	Outcome not a population level measure: denominator not population in need
Yawson, A. E., et al. (2017). "Regional disparities in immunization services in Ghana through a bottleneck analysis approach: Implications for sustaining national gains in immunization." Archives of Public Health 75(1).	Relevance
Yawson, A. E., et al. (2017). "The lancet series nutritional interventions in Ghana: a determinants analysis approach to inform nutrition strategic planning." BMC Nutr. 3:27.(doi): 10.1186/s40795-40017-40147-40791. eCollection 42017.	Relevance
Yugbare Belemsaga, D., et al. (2018). "Integration of postpartum care into child health and immunization services in Burkina Faso: findings from a cross-sectional study." Reproductive Health 15(1): 171.	Relevance
Zhang, L., et al. (2018). "Analysis of sero-epidemiological characteristics of varicella in healthy children in Jiangsu Province, China." BMC Infectious Diseases 18(1): 563.	Study type

Table S3 Overview of included studies

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Aaron et al. 2016 (63)	Nutrition: Complementary Feeding Supplement	1 district in the Northern Region & 3 districts in the Eastern Region of Ghana	To assess the effectiveness of the two delivery two sales-based approaches to distributing a complementary food supplement to infants and young children.	Effective Coverage: the proportion of children aged 6 to 24 months whose caregiver fed the child the product at least once in the previous 7 days.	Number of children who consumed the product in the last 7 days.	Children aged between 6 and 24 months. (1) all children used as a measure of overall programme performance (2) all children defined as at risk used as a measure of how well delivery model addressed needs.	• Household survey • date n/r	n/a	Receipt and timing of supplement based on caregiver's self-report *Binary: taken as prescribed vs. not*	None given, adapted Tanahashi's model.	• Coverage measures, 3 steps: message coverage, contact coverage, & effective coverage	None given
Baker et al. 2015 (55) * EQUIP study	(1) Childbirth: use of partograph to monitor labour (2) Childbirth: active management of third stage of labour (AMTSL) (3) Postpartum care in a health facility within 48hrs of delivery	2 rural districts in Tanzania	To estimate effective coverage of maternal and newborn health interventions & identify bottlenecks in their implementation in rural districts of the United Republic of Tanzania.	Effective coverage: the proportion of mothers who used a health facility that was ready to deliver the intervention and who actually received the intervention. (1) Proportion who satisfy the definition for availability coverage and who used a facility in which a health worker reported using a partograph during the last delivery attended. (2) Proportion who satisfy the definition for availability coverage and who used a facility in which a health worker reported giving an oxytocic agent during the last delivery attended (3) Proportion who satisfy the	Number of women who gave birth in HF that was able to deliver the intervention and received the intervention	All women aged 13-49 yrs with live birth in previous 12mnths	• Household survey • Nov 2011 – Dec 2012	• Facility survey • incl. interview with HCW on actions taken during last delivery • April-July 2012	Availability of human resources, drugs & equipment needed to deliver intervention & receipt of interventions based on HCW reports. (1) partograph available & HCW reported using a partograph during the last delivery attended (2) sterile syringes & needles and oxytocin or ergometrine available & HCW reported giving an oxytocic agent during the last delivery attended (3) offering postpartum care with iron supplements available & women reported being checked within 48 hours of delivery *Binary: all components present vs. not*	None given, adapted Tanahashi's model to develop an implementation pathway.	• Implementation pathway, 4 steps: target population, accessibility coverage (timely utilisation of a health facility), availability coverage (health facility readiness) and effective coverage (receives the interventions as intended).	Indicators chosen affect the coverage estimates. Used indicators that reflected only the minimum conditions required for judging completeness of implementation. HCW reports of actions taken subject to social desirability bias, could result in over reporting.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
				definition for availability coverage and who report being checked within 48 hours of delivery								
Carter et al. 2018 (45)	Sick child care: treatment for diarrhoea, fever, ARI or a combination	1 province in Zambia; two urban and three rural health facility catchment	To assess the feasibility of collecting geographically and temporally concurrent household and health care provider data at a small scale in both an urban and rural setting to perform exact-match linking. To quantify the degree of bias introduced by using less rigorous linking methods, including multiple ecological linking methods and utilization of facility-only health care provider assessments.	Input based effective coverage: average structural quality experienced by all sick children (based on their reported care-seeking behaviour and linked source of care).	Structural quality score of either specific reported source of care or nearest provider.	All children under 5 reported to have at least one DHS illness (diarrhoea, fever, ARI or a combination)	• Household survey based on DHS • March 2016	• Provider assessment based on SARA. • HCW knowledge assessed using clinical case scenarios. • Jan – March 2016.	Structural quality, 6 domains: (i) diagnostics, (ii) basic medicines, (iii) severe/complicated illness medicines, (iv) human resources, (v) availability of services, commodities, and (vi) HCW knowledge. *Average score: equal weight given to each domain*	None given, authors state selected the minimum inputs required.	• Composite measure • EC estimates presented by different linking approaches	Measure based on facility capacity to provide care; no measure of process quality or quantitative health gain. Indicators were considered the minimum inputs for appropriate care: the basic commodities required to diagnosis and treat common child illness, along with the human resources and clinical knowledge to apply them correctly
Carvajal-Aguirre et al. 2017 (31)	Postnatal care within 48 hours	17 countries in sub-Saharan Africa	To analyse the co–coverage of content interventions used as proxy for quality of care received by women during antenatal care and by the newborn during postnatal period using data from	Content coverage: Percentage of women with a live birth in last 2 years who were attended by a skilled birth attendant and received all 7 content interventions	Attended by a skilled birth attendant and received all 7 content interventions	Women with a surviving infant under 2 yrs	• DHS • 2010 - 2015	n/a	Receipt of 7 interventions based on women's self-reports *Binary: all components present vs. not*	None given	• Composite score • Compares gap between contact and content coverage for each intervention separately and all 7 interventions combined.	Only able to include interventions available in HH survey across countries included. Measures based on mother's recall of care, may be subject to recall bias.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
			nationally representative surveys. To compare this co–coverage estimate with the global coverage indicators assessing contacts with health system to highlight the gap between contact and content.									
Hategeka et al. 2020 (52)	(1) Postpartum check-up before discharge (2) Sick child care: treatment of suspected pneumonia (3) Sick child care: treatment of diarrhoea (4) Sick child care: treatment of fever	Rwanda	To assess effective coverage of MCH services in Rwanda, equity in effective coverage and its subnational distribution over the MDG era.	Effective coverage: Propn of individuals in need of MCH services who used the service and received quality MCH services	(1) Number women who delivered in a facility & were examined or asked about their health within 1 hour of delivery (2) Number children received antibiotics when seeking care at a facility for symptoms of pneumonia (3) Number children received ORT when seeking care at a facility for diarrhoea (4) Number children tested for malaria	(1) Women aged 15-49 yrs with 1+ births in preceding 5yrs, whose most recent pregnancy lead to a live birth (2) All children <5 who, in the past 2 weeks, suffered from symptoms consistent with pneumonia (3) All children <5 who had diarrhoea in past 2 wks (4) All children <5 yrs who had fever in the past 2 wks	• DHS • 2010 & 2015	n/a	Two domains of processes of care: competent care (treatment & assessment), and system competence (timely care) based on women's self-reports (1) Assessment & timely care: examined or asked about health before discharge & checked within 1 hour after giving birth. (2-3) Treatment: received antibiotics/ORT (4) Assessment: had blood taken from heel or finger for testing *Binary: received or not*	• Lancet Global Health Commission on High-Quality Health Systems in the SDG era International guidelines: • WHO Safe Childbirth Check list • Integrated Management of Childhood Illness (IMCI) guidelines	• Composite measure • Compared national average change in crude & effective coverage between 2010 & 2015	Likely overestimate EC because: Quality measures include only a limited no. of recommended items. Dichotomous items (yes/no response) do not measure quality comprehensively. Other relevant indicators, such as appropriate assessment and diagnostic tests, timeliness of care and other preventive and curative treatments for each condition, are not available in the RDHS. Self-reported data; evidence that women's ability to accurately recall care received suggests poor for some indicators.
Joseph et al. 2020 (39)	Childbirth: post-delivery care	Malawi	To use health system and population information to define nutrition quality-adjusted coverage metrics and quantify their impact on breastfeeding and birthweight.	Quality-adjusted coverage: The proportion of deliveries in HF that received nutrition intervention.	Likelihood of receipt of interventions based on geographic area and delivery facility type: woman assigned the district average score by facility type based on reported place of care seeking.	Women with a live birth in the last 2 yrs	• MICS • 2013-2014	• SPA • 2013	Direct observations of 3 interventions received: breastfeeding initiation within 1 hour of delivery, skin-to-skin and rooming in. *Average score across facility: equal weight given to each domain*	• None given	• Composite measure	Women linked based on reported source of care, so care might not be reflected of true quality experienced. Data sources not perfectly contemporaneous. Births captured up to 2 years before the survey period so predate SPA and quality of care might vary across this time period.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Kanyangarara et al. 2018 (32)	Childbirth: obstetric service	17 LMIC: Bangladesh, Benin, Burkina Faso, DRC, Haiti, Kenya, Malawi, Mauritania, Namibia, Nepal, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zimbabwe	To assess obstetric service availability, readiness and coverage within and between 17 low- and middle-income countries.	Population-level coverage of obstetric services: (1) The proportion of deliveries in HF with EmOC (basic or comprehensive) functionality (service availability) (2) The proportion of deliveries in HF ready to provide obstetric services (facility readiness)	Number of deliveries occurring in each stratum (based on health facility type and managing authority), assigned average stratum score for: (1) service availability (2) facility readiness	Propn of recent live births	• DHS or MICS • 2007 - 2015	• SARA or SPA • 2007 - 2015	(1) Service availability: reported performance of 7 basic & 2 comprehensive signal functions *Categorical: four levels of functionality based on number and type of signal functions performed* (2) Facility readiness reported/observed availability of 23 items across 4-domains: (i) general requirements, (ii) staff & guidelines, (iii) equipment, (iv) medicines & commodities. *Binary score: threshold (> 20 items present)* Estimated indicators of service availability and readiness for each strata of health facility (based on health facility type and managing authority)	Systematic review: • Gabrysch et al. 2012, New Signal Functions to Measure the Ability of Health Facilities to Provide Routine and Emergency Newborn Care • Signal functions were excluded where not collected across all health facility surveys included in the analysis. Classification of facility functionality based on international guidelines: • WHO. Monitoring emergency obstetric care: a handbook. WHO: Geneva; 2009 • WHO's SARA theoretical framework	• Composite measure • Comparison across countries • Service availability & facility readiness adjusted coverage presented separately	Approach assumed that all the women who delivered in a health facility assigned to a specific stratum experienced the "average" service availability and readiness for that stratum.
Kemp et al. 2018 (47)	Childbirth: facility based delivery	Haiti	To explore facility readiness as a predictor of facility-based delivery in Haiti, controlling for other supply- and demand-side factors. Our challenge was to characterize readiness of delivery-related services, link that readiness to nearby births, and avoid the misclassification errors and strong assumptions made by previous studies.	Facility readiness: the level of delivery-related service readiness available and accessible to women living in each sampling cluster.	HF readiness for each health facility providing delivery services	All births occurring in 2 yrs preceding survey	• DHS • 2012	• SPA • 2013	Facility readiness, 52 binary indicators of general service readiness & 18 binary indicators of delivery-specific readiness based on SARA. No further details given *Average score calculated at cluster level*	Based on the WHO's SARA theoretical framework.	• Composite measure	DHS birth data were collected before the SPA facility data; believe SPA offered plausible estimates of the service readiness environment surrounding births given that health facility readiness tends to be stable over a two-year timeframe. Results rely on the completeness, consistency, and validity of the DHS and SPA datasets. SPA used observation of equipment and

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
												services rather than self-reported data, improving the validity of the readiness data. Composite score cannot discriminate between a facility adding latex gloves to its inventory from one acquiring electricity. Further work should test whether the service readiness factors measured by SPA actually align with the areas of quality that most drive demand for facility-based maternity services.
Koulidiati et al. 2018 (42)	Sick child care: treatment of illness	6 low performing regions in Burkina Faso	To estimate crude coverage and effective coverage of U5YO children in Burkina Faso focused on curative care provided by primary-level health facilities	Effective coverage: the propn of all children under 5 in need who actually sought care at a facility categorised as least high or intermediate performance quality.	Children sought care at a facility categorised as high or intermediate performance quality	All children under five that had an illness episode in the previous four weeks	• Household survey • Oct 2013 - Feb 2014	• Facility survey for inventory • Patient provider observation • Vignette-based knowledge assessment • Oct 2013 - Feb 2014	Three dimensions: (1) 9 process indicators based on observations related to performance of management of common childhood diseases and 2 related input indicators; (2) 11 process indicators based on vignettes related to theoretical management of severe childhood diseases and 7 related inputs; (3) general service readiness based on 5 structural indicators. *Categorical: high/intermediate/low* Based on facility or service-specific score. Facilities that met different criteria levels for each dimension, were assigned to the lower level	Based on the Donabedian framework & indices developed by Gouws et al. 2005, Measuring the quality of child health care at first-level facilities	• Composite measure; disaggregated by high performing facilities and both high & intermediate quality		Quality of care based on content of care and does not capture aspects such as patient adherence to treatment or health outcomes. Assumes every reported illness episode actually requires a medical care visit; might overestimate true need and therefore underestimate coverage.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Larson et al. 2017 (53)	Childbirth: obstetric care	PHCs in 1 rural region in Tanzania	Linked population and facility data to assess the effective coverage of obstetric care for women in rural Tanzania, explore the bottlenecks in effective coverage and estimate wealth-based differences in receipt of effective care.	Effective coverage: the propn of women who delivered in facilities providing good care on successive dimensions of quality, beginning with basic infrastructure, followed by equipment and supplies, health worker knowledge and competence, provision of routine obstetric services and ending with provision of basic emergency obstetric care.	Women delivering at a facility receiving at least the minimum threshold of quality	All women ≥15 years who delivered a child in yr preceding interview.	• Household interviews • Jan 2016 – April 2016	• Facility audits • Jan 2016 – Feb 2016 (extracted data from facility register Jan-Dec 2015) • Health worker interviews (incl. 2 clinical vignettes) • Jan 2016 – April 2016	5 dimensions: (1) facility infrastructure; (2) availability of equipment, supplies & medicines; (3) HCW knowledge & competence (tested); (4) provision of routine obstetric services recorded in facility register; (5) provision of emergency obstetric and newborn services (BEmONC). *Categorical: High/minimum/less than minimum* Calculated the mean HCW knowledge score & mean input score for other 4 dimensions High threshold = ≥90% of tracer indicators were complete or for the knowledge and skill dimension if the average health worker score was 80% Minimum threshold = 50% completion of indicators.	Tracer indicators for equipment, supplies and medications were determined from the Tanzanian Ministry of Health required list, previously reported indices, and an expert review panel.	• • Quality cascade, 5 steps: infrastructure, equipment, HCW knowledge, provision of routine care, provision BEmONC	Thresholds for minimum quality have not been empirically defined, requiring somewhat subjective judgment of what constitutes adequate care. Threshold selected for minimum quality (50% completion) was permissive and thus represents the best-case scenario. Indicators for routine services were limited to those recorded in the facility registers. Conducted from facility-level data and may not reflect the actual experiences of each individual woman on the day of her visit.
Leslie et al. 2017 (33)	Sick child care: treatment of diarrhoea, fever or ARI	8 countries: Haiti, Kenya, Malawi, Namibia, Senegal, Rwanda, Tanzania & Uganda	To combine nationally representative facility and population survey data from eight countries to evaluate effective coverage of three primary care services at the subnational level.	Effective coverage: multiplied use of healthcare by average quality	Number of children under-5 who sought care from a formal provider. Each sick child was assigned the structural quality score for the reported category of source of care sought.	Children under 5 who had experienced diarrhoea, fever or acute respiratory illness in the prior 2 wks.	• DHS or MICS • 2014 or 2015-2016	• SPA • Uganda, Rwanda 2007; • Namibia 2009; • Kenya 2010; • Haiti, • Malawi 2013; • Senegal 2013-14; • Tanzania 2015	Technical quality based on observations of essential clinical actions. 4 domains: history taking, routine examination, drug administration & immunization, and client education & counselling *Average score* Calculated as the percent of actions completed out of items assessed per country.	International guidelines: • WHO. Integrated Management of Childhood Illness: Chart Booklet. Geneva, Switzerland: WHO, 2014	• Composite measure • EC calculated at sub-national and national level; compare between and within countries.	Data sources spanned 2007-2016, limiting contemporaneous cross-country comparisons. Facility-based estimates of healthcare quality may not fully reflect use patterns.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Leslie et al. 2019 (37)	(1) Childbirth: delivery care (2) Childbirth: newborn care (3) sick child care: treatment of diarrhoea (4) sick child care: treatment of respiratory illness	Mexico	To estimate effective coverage and its regional inequalities within IMSS based on routine health information and to identify the challenges in generating comprehensive estimates of health system performance.	Effective coverage: the number of individuals experiencing high-quality outcomes divided by the number in need of the service.	Number of individuals receiving care from an IMSS facility and experienced a positive health outcome	Population in of individuals with the symptom or condition requiring health service in strata by state and age group: (1) delivery: Women with live birth in last year (2) newborn: born alive in last year (3) diarrhoea: parental report of child under 5 experiencing at least 3 days of diarrhoea or diarrhoea plus fever (4) respiratory illness: child under 5 experiencing flu, cough, bronchitis, sore throat or pain in his/her ears in the past 2 weeks	• Mexican National Health and Nutrition Survey (ENSANUT) • 2012	• IMSS Performance Indicators; based on health information systems. • 2016	Health outcome: (1) delivery: without complication or death (subtracting maternal complications and mortality from total cases). (2) newborn: live births reaching 28 days without death due to respiratory infection, nosocomial infection or sepsis (3) diarrhoea: visits that did not result in hospitalisation due to diarrhoea (4) respiratory illness: visits that did not result in hospitalization due to non chronic respiratory condition As outcome not entirely amenable to health services and hence will occur even in the presence of a high-quality health system, rescaled effective coverage against a global benchmark.	None given	• Cascade, 3 steps: in need of services, using service, and experiencing high-quality outcomes	Assessment of quality using neonatal mortality without consideration of avoidable morbidity likely overestimated quality.
Leyvraz et al. 2016a (61)	Nutrition: Fortified Complementary Foods	Abidjan, Cote d'Ivoire	To determine the coverage of the Project de Promotion de l'Alimentation de Complément Enrichie du Jeune Enfant en Côte d'Ivoire (PACE) program among children 6–23 months of age living in Abidjan, identify the major barriers to coverage of the program, and formulate recommendations for future	Effective coverage: the proportion of children aged 6-23 months whose caregiver has fed the participating child the project-specific fortified complementary food (Farinor or Nutribon) at least once in the past 7 days	The number of children whose caregiver had heard of the project-specific fortified complementary food (Farinor or Nutribon) and had fed the child the product at least once in the last 7 days.	Number of children aged 0 to 23 mnths (1) All children (2) Children from poor households and with poor feeding practices	• Household survey • September-October 2014	n/a	Receipt and timing of supplement based on caregiver's report *Binary: taken as prescribed vs. not*	None given, adapted Tanahashi's model	• Coverage levels, 4 steps: message coverage, contact coverage, partial coverage & effective coverage	None given

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
			program activities.									
Leyvraz et al. 2016b (62)	Nutrition: Fortified Complementary Foods	Telangana State, India	To determine the coverage of the fortified complementary food program managed by Andhra Pradesh Foods (AP Foods), a state government-owned food manufacturing company among children 6–35 months of age living in Telangana state, identify the major barriers to coverage of the program, and formulate recommendations for future program activities.	Effective coverage: the proportion of children that always consume the project-specific fortified complementary food (Bal Amrutham)	The number of children whose caregiver received the project-specific fortified complementary food (Bal Amrutham) and who always consumed the ration.	Number of children aged 0 to 35 mnths (1) All children (2) Children at risk of poverty and with poor feeding practices.	• Household survey • November-December 2014	n/a	Receipt and timing of supplement based on caregiver's report *Binary: taken as prescribed vs. not*	None given, adapted Tanahashi's model	• Coverage and utilisation levels, 4 steps: message coverage, contact coverage, partial coverage & effective coverage	None given
Leyvraz et al. 2018 (60)	Nutrition: Micronutrient powders	7 neighbourhoods of Nairobi County, Kenya	To determine the baseline MNP coverage and utilization mainly from existing free distribution through the government (i.e., to determine the coverage of the existing MNP program in the area), especially among subgroups that may be more vulnerable to inadequate nutrient intake as a result of poverty or poor IYCF practices.	Effective coverage: The proportion of children aged 6-23 months that consumed at least 3 sachets of the micronutrient powder in the last week	The number of children whose caregivers had ever heard of MNP and consumed at least 3 sachets of the MNP in the last week	Number of children aged 6 to 23 mnths (1) All children (2) Children at risk of poverty or poor feeding practices	• Household survey • date n/r	n/a	Receipt and timing of supplement based on caregiver's report *Binary: taken as prescribed vs. not*	None given, adapted Tanahashi's model	• Coverage processes, 4 steps: message coverage, contact coverage, partial coverage & effective coverage	The main limitation of this study was that the results were not representative of the country, or of all Nairobi. The neighbourhoods included in the survey were selected based on their inclusion in the project area of a new MNP program.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Marchant et al. 2015 (34)	(1) Childbirth: Prevention of haemorrhage (2) Postpartum check within 48 hours (3) Postnatal check within 48 hours	4 regions in Ethiopia, 1 state in India, 1 state in Nigeria	To propose a measurement method for evaluating the quality of health care for mothers and newborns that links the coverage of each type of contact to the content of care that should take place during those contacts to estimate the coverage of high quality contacts at the population level.	High quality contacts: (1) The percent of women who were attended at birth by a skilled birth attendant and received AMTSL (2) The percent of women who had a post-partum check within 48 hours of birth and for whom all five post-partum processes were met - exclude this? (3) The percent of newborns who had a post-natal check within 48 hours of birth and for whom all five post-natal processes were met	Contacts during which recommended set of processes for routine health care were met	(1-2) women aged 13-49 with a live birth in previous 12 mnths (3) newborns born alive in previous 12 mnths	• Household survey • 2012	• Facility survey • Frontline worker survey: HCW who carried out last delivery recorded in maternity register • 2012	Routine process of care based on HCW reports (1) Attended at birth by a skilled birth attendant and HCW reported received AMTSL. (2) Five post-partum processes (3) Five post-natal processes *Binary: all present vs. not*	International guidelines: • Partnership for Maternal Newborn & Child Health and the Aga Khan University. Essential Interventions, Commodities and Guidelines for Reproductive, Maternal, Newborn and Child Health. A Global Review of the Key Interventions Related to Reproductive, Maternal Newborn and Child Health (RMNCH). 2011.	• Composite score • EC measure presented at country or state level	SBA responses about their own behaviour at the last birth they attended. Birth attendants may be biased towards providing positive responses about their own behaviours, meaning that the method provides a 'most optimistic' estimate of coverage that can be applied in a standardised way.
Millar et al. 2014 (50)	Sick child care: Malaria	Bauchi and Sokoto States, Nigeria	To describe the current care-seeking and treatment pattern for children under five with fever in Northern Nigeria. Determine how many children with fever received treatment consistent with NNCP/WHO standards and which factors predict if a child under five with fever is taking to treatment.	Treatment pathway: Children under the age of five who sought prompt treatment at a provider and received it according to Nigeria National Malaria Control Program (NMCP)/WHO standards	Number of children who received ACT	Number of children aged 0-59 months that had malaria symptoms	• Household survey • November - December 2012	n/a	Receipt and timeliness of treatment based on caregiver's report *Binary: all components or not*	Prompt treatment based on recommendations from the RBM Partnership: • RBM: Progress & Impact Series: Country Reports: Focus on Nigeria. Geneva: Roll Back Malaria Partnership; 2012. Standard case management pathway based on international guidelines: • WHO: Guidelines for the Treatment of Malaria. 2nd edition. Geneva: WHO; 2010.	• Treatment pathway, 4 steps: malaria symptoms, sought prompt treatment, received a blood test, received ACT	Relies on women's self-reports; including for blood test results.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Mmanga et al. 2021 (59)	Vaccination: Full vaccination coverage	Malawi	To describe the trend in immunization coverage, dropout rates and effective immunization coverages (FVC) among children aged 12–23 months in Malawi.	Effective Immunization Coverage: proportion of children aged 12–23 month who received the recommended EPI vaccine antigens	Number of children fully vaccinated by 12–23 months according to the vaccination calendar timeline	Number of children under 12 years eligible for full vaccination	• DHS • 2004, 2010, 2015-16	n/a	Children aged 12–23 months who received BCG, OPV3, Penta3, PCV3, Rota2 and MCV1 vaccines *Binary: received or not*	Malawi Expanded Programme on Immunization (EPI) schedule	• Bottleneck analysis framework, 4 steps: initial utilization (received either BCG or Penta1), continuous utilization (received Penta 3), adequate coverage (received MR1), full vaccination coverage (BCG, OPV3, Penta3, PCV3, RV2 and MCV1)	DHS does not have data on supply determinants of services (commodities, human resources and geographic access) so only able to focus on demand and quality determinants of services.
Mokdad et al. 2015 (35) *Salud Mesoamérica	Vaccination: MMR	Poorest quintile of the population in 6 countries: El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama.	To assess the presence of missed opportunities to vaccinate using a large household survey in Mesoamerica. To estimate the potential increase in immunization coverage and reduction in days at risk if every opportunity to vaccinate a child was used, they analysed vaccination histories of children 11–59 months of age from large household surveys in Mesoamerica.	Missed opportunity: (1) Timely MMR coverage according to card only considering timeliness (2) MMR coverage among children attending facilities with MMR in stock on day of survey (3) MMR coverage among children attending facilities with MMR stock-out in 3 mnths prior to the survey (4) MMR coverage among children attending facilities with ORS in stock on day of survey	(1) Children aged 13 months or older with a MMR vaccine given between 11.5 and 13.5 months (2) Children with required number of doses for age with proper time interval and not before eligibility window for MMR coverage attending facilities with MMR in stock on day of health facility survey 3) Children with required number of doses for age with proper time interval and not before eligibility window for MMR out of stock in three months prior to health facility survey; (4) Children with required number of doses for age with proper time interval and not before eligibility	Number of children aged 11-59 months with a vaccine card	• Household survey, incl. review of vaccination card • March 2011 - August 2013.	• SM2015 baseline health facility survey	(1) Timely vaccination as recorded on card: vaccine administered between 11 and 13 months *Binary: timely or not* (2-4) Facility readiness: Availability of MMR vaccine and oral rehydration salts *Binary: present or not*	National guidelines: MMR vaccination required at 12 months in all countries in Mesoamerica No details given on other components	• (1) Coverage cascade, 3 steps: owning a health card, vaccine coverage and timeliness • (2, 3 & 4) Composite score	Calculated missed opportunities using vaccination visits only as data on other health care visits not available. Using all visits as possibilities for vaccination would results in increased coverage.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
					window for MMR coverage attending facilities with ORS in stock on day of survey							
Munos et al. 2018 (43)	(1) Childbirth: Labour & delivery (2) Childbirth: immediate newborn care (3) post-discharge postnatal care for mother and baby within 2 days of birth (4) sick child care: treatment fever, cough or diarrhoea	Savanes region of Côte d'Ivoire	To better understand the feasibility and comparability of exact-match and different ecological methods for linking household and health provider surveys to obtain effective coverage measures.	(1) Structure-adjusted coverage: proportion of women or children visiting a facility that is ready to provide care (2) Process-adjusted coverage: proportion of women or children visiting a facility that provides actual processes of care	Average structural or process quality scores for the provider category reported as the source of care.	(1-3) Women reported a live birth in the 2 yrs preceding the survey (4) Mothers of children under-5 years who reported child had fever, cough or diarrhoea in 2 weeks before survey	• MICS; 6 Qs added to identify exact sources of care. • May – July 2016	• Facility inventory adapted from SPA & SARA. • Caseload from facility registers. • HCW survey • Observations of postnatal and sick child consultation • May-June 2016	Three domains of structural quality: (1) service availability; (2) availability of drugs, diagnostics & commodities; (3) training, supervision & availability of guidelines. Process quality based on observed processes of care, including the patient's activities, the provider's activities, and the interactions between the two. *Average score* Number of items present divided by total number of items. Score ranged from 0 to 1. Training variable: proportion of HCW at facility who had received training.	Used Donabedian definitions of structural quality and process quality. SARA analysis guide for structural quality. Process quality used international guidelines: • WHO Safe Childbirth Checklist. • WHO Recommendations on Postnatal Care of the Mother and Newborn. WHO Guidelines Approved by the Guidelines Review Committee. Geneva: WHO; 2013 • WHO. Integrated Management of Childhood Illness. Chart Booklet. Geneva: WHO; 2014	• Composite measure • Structure & process adjusted coverage presented separately • EC estimates presented by different linking approach.	Relies on women reporting the source of are visited; although errors likely to be rare. Assumes no error in our measurement of facility quality because collected data from all facilities.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Murphy et al. 2018 (38) * Nairobi Newborn Study	Inpatient neonatal care	Nairobi City County, Kenya	To report on the quality of the process of care delivered to small and sick inpatient newborns across diverse facility settings in Nairobi with a view to understanding effective coverage.	Effective coverage: Proportion of newborns needing care attending a facility providing high-quality care	Number of neonates attending a facility providing high quality care	Number of newborns requiring care; estimated by applying the rate of live births requiring inpatient services (183 per 1000 live births) to the total number of live births in the study region between mid-2014 to mid-2015	None: • Estimated number of live births in Nairobi City County in 2017 by applying the Nairobi City County crude birth rate obtained from the Kenyan 2014 demographic and health survey to population estimates for the County, derived from the 2009 national census and adjusted for population growth from 2009 to 2017.	• Facility assessment • Neonatal medical records review • July 2014 - June 2015	Process quality based on medical records across 6 domains: (i) documentation of newborn characteristics, (ii) documentation of signs and symptoms, (iii) evidence of monitoring, (iv) correct antibiotic dose, (v) correct oxygen treatment and (vi) correct fluids and feeds prescribed. Structural quality across 8 domains: (i) infrastructure, (ii) laboratory services, (iii) hygiene equipment, (iv) safe delivery equipment and drugs for mothers, (v) resuscitation equipment for newborns on the delivery ward, (vi) essential equipment in the newborn unit (NBU), (vii) intravenous fluids and feeds in the NBU and (viii) NBU drugs. *Categorical: high/medium/low* Average process quality >60% & structure score >=80% considered high quality	Dosage of antibiotics or fluids and feeds based on national guidelines. No details given on other components	• Composite measure; disaggregated by low, medium & high quality	Use of medical records limits assessment to indicators that are routinely documented. Medical records are not standardised across facilities, may have contributed to lower performance in non-public-sector facilities. Quality of care defined based on national standards of care; may not apply to private sector. Not able to assess mortality.
Nesbitt et al. 2013 (54) *Newhints trial	Childbirth: Intrapartum and immediate newborn care	7 districts in Brong Ahafo, Ghana	To evaluate quality of routine and emergency intrapartum and postnatal care using a health facility assessment, and to estimate "effective coverage" of skilled attendance.	Effective coverage: proportion of births in facilities of high quality	Delivery in a facility with "high" or "highest" quality in all four dimensions	Live births with known birthplace	• Surveillance data of all women of child bearing age in the Newhints trial area • Nov 2008 – Dec 2009	• Health facility assessment • Oct-Nov 2010	Signal functions and corresponding drugs & equipment across, 4 dimensions: (1) routine delivery care, including labour and immediate postnatal care, (2) emergency obstetric care (EmOC), (3) emergency newborn care (EmNC), and	Based on functions included in other large-scale facility assessments in consultation with local clinicians: • Gabrysch et al. 2012, New Signal Functions to Measure the Ability of	• Composite measure • Estimates coverage & quality gap between coverage of facility delivery and provision of high quality care. Presented for each quality dimension separately and all 4 dimensions combined.	Relied on reported performance of signal functions as did not observe provision of care. May have overestimated quality of functions that did not validate with tracer items.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
									(4) non-medical quality. *Categorical: highest/ basic/ intermediate/ low/ lowest* Calculated based on reported availability of drugs & equipment, reported frequency of performance of signal functions, number of trained health professionals & capacity for referral.	Health Facilities to Provide Routine and Emergency Newborn Care		
Nguhiu et al. 2017 (40)	(1) Childbirth: skilled delivery & perinatal care (2) Vaccination: complete set of basic vaccines (3) Sick child care: care seeking for acute respiratory illness/fever (4) Exclusive breastfeeding during first 6 months of life (5) Sick child care: management of diarrhoea (6) Insecticide treated nets	Kenya	To estimate the levels of and inequities in EC of maternal and child health (MCH) services in Kenya, as a means of tracking the country's progress towards UHC.	Effective coverage: (1, 2 & 3) Propn of individuals in need of intervention who attended a health facility that was ready to provide care. (4, 5 & 6) Propn of individuals in need of intervention who reported receipt of recommended components of care. Overall EC estimate calculated as the average of 8 intervention-specific EC * Note data on 2 interventions (family planning and ANC) not extracted	(1) Women attended by a SBA at most recent birth adjusted for facility quality (2) All children who received complete set of vaccines adjusted for facility quality (3) All children who sought advice from a medical provider adjusted for facility quality (4) All children exclusively breastfed within the last 24hrs. (5) All children given ORT or increased fluids (6) All pregnant women & children who lived in a house with an ITN and slept under the net the previous night	(1) All women 15–49 yrs old with at least one child under 5 yrs (2) All children alive aged 12-23 mnths (3) All children under 5 yrs reported to have had acute respiratory illness and/or fever in preceding 2 wks (4) All children aged 0-5 mths (5) All children under 5 yrs reported to have had diarrhoea in preceding 4 wks (6) All children (age NR assume under 5 yrs)	• DHS • 2003, 2008-2009, 2014	• Interventions 1-3 only: • SPA • 2004, 2010	(1) HCW reports of 9 items incl. structural features, essential newborn care practices and administration of key medicines (2 & 3) quality of primary care for children based on observed or HCW reports for 7 items incl. structural features and processes of care *Average score* Calculated at the provincial level (4, 5 & 6) Receipt of intervention based on respondent's report. *Average score*	None given	• Composite measure • Presents change in EC from 2003 to 2014	Few other reliable national data sources in Kenya other than DHS (MICS only conducted in selected regions and not representative at country level) Good estimates of quality of care requires information from different datasets; not available for all interventions. For those interventions where available in KSPA quality measure was applied equally to all individuals.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Nguyen et al. 2021 (44)	(1) Childbirth: birth care (2) Child Growth Monitoring (3) Sick child care: nutrition education, vit A supplementation, deworming, anaemia management ORS and zinc for diarrhoea	Bangladesh	To adjust contact-based health coverage estimates in Bangladesh, taking into consideration the inputs required to deliver quality nutrition interventions across the continuum of care, specifically ANC and delivery for women and growth monitoring and curative care for young children.	Input-adjusted coverage: the proportion of women/children who sought care at a facility accounting for the type of facility where care was sought * defines effective coverage using Marsh seven-step coverage framework	(1) Women 15–49 years old with at least one child under 5, whom for their most recent birth, reported delivery in a health facility (2 -3) All children who had diarrhoea or ARI symptoms for whom care was sought from a medical provider	(1) Women 15–49 years old with at least one child under 5 (2) All children alive between 0 and 59 months; (3) All children alive between 0 and 59 months who had diarrhoea or ARI in the last 2 weeks	• DHS • 2014	• SPA • 2014	Facility readiness, based on 5 attributes guided by SARA: (1) trained personnel, (2) guidelines, (3) equipment, (4) diagnostic capacity and (5) medicines. *Average score from 0 to 100* Calculated at facility-level and disaggregating by region and urban/rural location Five domains weighted equally within each measure.	Based on the WHO's SARA theoretical framework.	• Composite measure	Contact coverage based on woman's recall. Underestimate contact coverage of growth monitoring services if well children are frequently brought to health facilities for this purpose. SPA does not capture every aspect to measure facility readiness to provide nutrition interventions (such as the infrastructure to implement kangaroo mother care, calcium or food supplements for pregnant women, or IFA and food supplements for children). Data do not allow calculation of care cascade.
Nguyen et al. 2016 (57)	Nutrition: Complementary foods with micronutrient powders	4 provinces in Vietnam (Hai Phong, Thai Nguyen, Quang Nam, and Ca Mau in the South)	To present the pilot's design, implementation, coverage results, and MNP use and compliance by caregivers. To provide recommendations on how the results from this pilot could help inform the strategy on home fortification of complementary foods with MNPs for micronutrient deficiency prevention, and how this model could be scaled up in Vietnam.	Effective coverage: the proportion of children that consumed at least 3 sachets of the National Institute of Nutrition-produced micronutrient powder in the last week	Number of children aged 6-59 mnths that consumed at least 3 sachets of the National Institute of Nutrition-produced micronutrient powder in the last one week	Number of children aged 6-59 mnths	• Household survey • November - December 2014	n/a	Receipt and timing of supplement based on caregiver's report *Binary: taken as prescribed vs. not*	Consumption per week based on WHO recommendations and the Home Fortification Technical Advisory Group Programmatic Brief: • WHO. Guidelines: Use of Multiple Micronutrients Powders for Home Fortification of Foods Consumed by Infants and Children 6–23 Months of Age. 2011. • HF-TAG. Programmatic Guidance Brief on Use of Micronutrient Powders (MNP) for Home Fortification.	• Coverage level, 4 steps: message coverage, contact coverage, partial coverage & effective coverage	Data was collected from caregivers at health centres which could have biased responses. Used one-week recall period to avoid recall bias. Questionnaire was developed to have harmonized questions for countries implementing MNP programs globally, some relevant indicators that would have helped better understand caregivers' behaviours/purchase trends/use of Bibomix in Vietnam were missing.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Okawa et al. 2019a (49)	(1) Childbirth: peripartum care (2) postnatal care for mother & newborn	1 urban and 1 rural region, Myanmar	To assess the contact of women and their newborns with healthcare providers, quality of care and quality-adjusted contacts during ANC, delivery and PNC, and to identify factors associated with having adequate contact and receiving high-quality care in Myanmar.	Quality-adjusted contact: having adequate contact and receiving high-quality care.	(1) Attended by skilled care providers at a health care facility and receiving high-quality care. (2) At least 3 contacts for PNC, with first contact within 24 hrs postpartum and receiving high-quality care	All women 6 wks to 12 mnths postpartum	• Household survey • March 2016	n/a	Content care based on women's self-reports. (1) 7 interventions for delivery *Binary: all items present vs. not* (2) 17 interventions for PNC (12 maternal and 5 newborn) *Binary: threshold (highest quality vs. rest)* High-quality: top 20 percentile	Domain of competent care defined in the high-quality health system framework: • Kruk et al. 2018 High-quality health systems in the Sustainable Development Goals era: time for a revolution. National guidelines: • Ministry of Health and Sports. Maternal and Child Health Handbook. Nay Pyi Taw, Myanmar: Ministry of Health and Sports, Unknown International guidelines: • WHO. Pregnancy, childbirth, postpartum and newborn care: a guide for essential practice. 3rd edn. Geneva, Switzerland: WHO, 2015.	• Composite measure .	Relies on women's recall on having received interventions. Only assessed one aspect of quality of care.
Okawa et al. 2019b (46) *EMBRACE trial	(1) Childbirth: peripartum care (2) postnatal care for mother & newborn	3 rural sites, Ghana	To examine the effects of the continuum of care intervention package on adequate contacts with healthcare providers and high-quality care by the mothers and their newborns compared with the standard maternal and newborn care under the national guidelines and to determine the	Adequate contacts with high quality care: Proportion of women who received adequate contacts with a healthcare provider and high-quality care.	(1) Skilled facility based delivery and received all components of care (2) 3 timely contacts and received all components of care	Women aged 15-49 yrs and delivered in 2 yrs prior to survey	• Household survey • July-Sept 2014 & Oct-Dec 2015	n/a	Content of care based on women's self-reports (1) Three care items (2) Based on the number and timing of contacts and receipt of 14 care items *Categorical: Inadequate contact regardless of quality, adequate contact with low or high quality care* Low quality: ≤13 care items	Process-of-care dimension in Donabedian's framework	• Composite measure. • Presents 3 outcomes: inadequate contact (≤2 contacts or non-timely contacts), adequate contact with low quality care and adequate contact with high quality care	No standardised measurement of quality available. Although value of each item not equal gave them equal weight.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
			factors associated with having adequate contacts with high-quality care.						High-quality: All care items received			
Sharma et al. 2017 (41)	Childbirth: delivery care	Kenya	To assess whether high quality maternal care is equitably distributed by (1) mapping the quality of maternal care in facilities located in poorer versus wealthier areas of Kenya; and (2) comparing the quality of maternal care	Population access to quality care: percentage of the population with access to minimally adequate standard of maternal care. (1) quality of maternal health care infrastructure (2) quality of delivery care	(1) Population living within 5-km radius of a facility with adequate maternal care infrastructure (2) Population living within 5-km radius of a facility with adequate delivery quality	Total population	• DHS • Oxford Poverty & Human Development Initiative • 2010	• SPA • 2014	Structural inputs (infrastructure, staffing & equipment) and clinical care processes. *Binary: threshold (adequate maternal care quality <0.75)* Averaged to provide a facility-level score from 0 to 1.	Using Donabedian's framework. Applied the quality of the process of intrapartum and immediate postpartum care (QoPIIPC) metric validated by Tripathi et al. 2015 [Development and Validation of an Index to Measure the Quality of Facility-Based Labor and Delivery Care Processes in Sub-Saharan Africa]	• Composite measure • Infrastructure & quality adjusted coverage presented separately	Small number of observations; difficult to obtain multiple observations for low-volume facilities. Lack of universally defined minimum quality standards, selected 0.75 threshold on premise that women should receive most basic items.
Sheff et al 2020 (48) * CHPS+ project	Vaccination: Complete set of basic vaccines	7 districts in Volta Region, Ghana	Using a modified version of the 1978 Tanahashi model as an analytical framework, aims to examine the system of care at the community level in Ghana's Volta Region to highlight the continued reforms needed to achieve UHC.	Quality coverage: the proportion of children who have received all vaccines mandated by Ghana's Expanded Programme on Immunisation by 24 months * Two additional coverage measures calculated separately and are not included in extraction (1) Availability coverage: the proportion of facilities with all health commodities and human	Number of children that received all vaccines on time	Number of children aged 12-23 months	• Household survey incl. review of vaccination card • April to October 2017	• Health facility assessment • July 2018 * used to calculate availability coverage	Receipt of complete package of vaccine on time: one dose of BCG at birth, three doses of the oral polio vaccine (excluding the dose given at birth), three doses of a DPT containing vaccine and hepatitis B vaccine at 6, 10, and 14 weeks, and one dose of the measles vaccine, all done by 24 months. *Binary: received or not*	Mandated by Ghana's Expanded Programme on Immunization (EPI)	• Modified Tanahashi model, 5 steps: (1) availability of health services & human resources, (2) geographic & financial accessibility, (3) initial contact, (4) continued utilisation, (5) quality coverage. *Calculates two measures: (1) potential coverage, which includes availability and accessibility, calculated at the facility level, (2) actual coverage combining initial contact, continued utilisation and quality coverage, calculated at the population level.	Survey instruments not designed specifically for the Tanahashi model; missing more specific information such as vaccine availability by antigen. Range of data sources needed to develop these models may not be widely available.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
				resources available (2) Accessibility coverage: the proportion of women who have a valid NHIS card and the proportion of women living within 5km of a facility								
Shibanuma et al. 2018 (58) * EMBRACE trial	(1) Childbirth: facility delivery (2) PNC within 48 hrs and around 2 and 6 weeks post-delivery	3 rural sites, Ghana	To compare continuum of care achievement in MNCH based on two measurements: (1) visits and (2) key components of services that were received. To compare the factors affecting continuum of care based on the two different measurements. Finally, to examine whether achievements differed across areas.	Continuum of Care achievement: Proportion of women and children who received MNCH services at delivery and post-delivery stages and who received the key components of MNCH services	(1) delivered at a health facility and received all components of care (2) both mother and newborn received timely PNC and all components of care	Women aged 15-49 yrs who had a live birth or stillbirth in 2 yr prior to survey.	• Household survey • July 2013	n/a	Receipt of key components of care based on women's self-reports *Binary: received all components or not*	International guidelines: • The Partnership for Maternal, Newborn & Child Health. A global review of the key interventions related to reproductive, maternal, newborn and child health (RMNCH). Geneva, Switzerland: PMNCH, 2011 • WHO. Guidelines on maternal, newborn, child and adolescent health approved by the WHO guidelines review committee: Recommendations on maternal and perinatal health. Geneva, Switzerland: WHO, 2013 • United Nations Children's Fund. Committing to child survival: A promise renewed. New	• Composite measure	Visits and receipt of care measured based on women's self-reports; included only key components that could be ascertained in interviews with women.

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
										York, NY, USA: United Nations Children's Fund, 2014. • WHO. Pregnancy, childbirth, postpartum, and newborn care: A guide for essential practice. Geneva, Switzerland: WHO, 2006 Published literature: • Singh et al. 2014 Postnatal care by provider type and neonatal death in sub-Saharan Africa: a multilevel analysis • Adegoke et al. 2009 Skilled birth attendance-lessons learnt Comments from health administrators at the study site.		
Smith et al. 2010 (51)	Sick child care: Malaria	3 districts (Tambacounda, Koumpentoum and Maka Coulibantang), Senegal	To analyse the application of a diagnostic approach to the coverage of prompt and effective treatment for febrile children in rural Senegal, assessing the critical steps at which children exit from the treatment pathway, stratified according to source of first advice or treatment.	Treatment pathway: Proportion of children under the age of five that received artesunate-amodiaquine (AS-AQ)	The number of children under the age of five that sought care within 48 hours and that received AS-AQ	Number of children aged under five years.	• Household survey • August-September 2008	n/a	Prompt and effective treatment based on self-reports *Binary: received or not*	Based on the National Malaria Control Programme, which specifies first line anti-malarial, and the Roll Back Malaria (RBM) access indicator.	• Treatment pathway, 5 steps: fever in the previous two weeks, sought any advice/treatment, care sought within 48 hours, received any anti-malarial, received an ACT.	• Limited sample size that led to wide confidence intervals; • Expectations of inaccuracies in the drugs provided given it is based on recall but this was minimized with the presentation of a photo during the interview;

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
Wang et al. 2019 (36)	Childbirth: facility delivery	6 countries: Bangladesh, Haiti, Malawi, Nepal, Senegal, and Tanzania	To estimate the effective coverage of obstetric and newborn care with a refined approach. This method takes into account different types of facilities where women delivered their births. We also estimated the uncertainty of the effective coverage estimates, which has not been commonly done.	Effective coverage: Calculated among individuals in need of care as the mathematical product of the use of the service and the quality of care provided.	Facility readiness for the type of facility where delivery care was sought.	Number of births in the 2 yrs preceding the survey	• DHS • Bangladesh: 2014, • Haiti: 2012, • Malawi: 2015-2016, • Nepal: 2016, • Senegal: 2016, • Tanzania: 2015-16	• SPA • Bangladesh: 2014, • Haiti: 2013, • Malawi: 2013-14, • Nepal: 2015, • Senegal: 2015, • Tanzania: 2014-15	Facility readiness, 6 domains: (1) comprehensive EOC, (2) newborn signal functions, (3) infrastructure, (4) equipment, (5) supplies & commodities, (6) the availability of guidelines trained personnel. *Average score: equal weight approach* Equal weight given to 6 domains and to all indicators within the same domain; sum of all domains standardised to have a maximum of 100.	International guidelines: • WHO. Service Availability and Readiness Assessment (SARA): An annual monitoring system for service delivery Reference Manual. Geneva, Switzerland: WHO; 2015. • Save the Children Federation I. Newborn indicators 2017 Systematic review: • Gabrysch et al. 2012, New Signal Functions to Measure the Ability of Health Facilities to Provide Routine and Emergency Newborn Care	• Composite measure	The readiness score itself cannot identify specific deficits. Facilities with a similar score could possess quite different specific tracer items.
Willey et al. 2018 (56) *EQUIP study	Childbirth: Basic emergency obstetric care	1 district in Uganda	To explore methods for linking access to skilled birth attendance (SBA) from household surveys to data on provision of care from facility surveys with the aim of estimating population level effective coverage reflecting access to quality care.	Effective coverage of skilled birth attendance in facilities ready to provide basic emergency obstetric and newborn care.	Product of prevalence of attendance by an SBA in a health facility and the prevalence of facility readiness	(1-2) women aged 13-49 with a live birth in previous 12 mnths (3) newborns born alive in previous 12 mnths (12	• HH survey • Jan 2012 – Dec 2013	• Facility survey • Nov 2012 – Feb 2013	Facility readiness, 6 components: (1) infrastructure, (2) infection prevention, (3) commodities to monitor and manage labour, (4) essential medicines, (5) commodities to provide neonatal resuscitation, (6) commodities to provide clean cord care. *Binary: all commodities for all 6 components available vs. not*	Systematic review: • Gabrysch et al. 2012, New Signal Functions to Measure the Ability of Health Facilities to Provide Routine and Emergency Newborn Care	• Composite measure • EC estimates presented by different linking approach.	Relied on women's self-report of skilled birth attendance, which is susceptible to measurement error. Facility readiness surveys represent availability on the day of survey; analysis revealed that some but not all commodities were stable over time. Quality measure focused on commodities; did not incorporate availability, training or capability of health facility staff attending births and caring for newborns, nor estimates of coverage of actual life-saving behaviours. EC

Reference	Intervention/service	Setting	Study aim(s)	Indicator	Numerator	Denominator	Data source(s)		Quality measure(s) (see Appendix D for individual items)	How quality measures derived	Results presented	Limitations of EC measure reported by author
							Household	Facility/provider				
												measure represents capacity to deliver quality care, rather than the quality of care delivered in practice.

Table S4 Childbirth and immediate newborn care

Study (data sources)	Baker et al. 2015 (55) (HH survey; HF assessment; HCW interview)		Joseph et al. 2020 (39) (MICS; SPA)	Kanyangarara et al. 2018 (32) (DHS; MICS; SARA; SPA)		Kemp et al. 2018 (47)* (DHS; SPA).	Larson et al. 2017 (53) (HH survey; HF assessment; HCW interview)	Leslie et al. 2019 (37) (ENSANUT [national survey]; HMIS)		Marchant et al. 2015 (34) (HH survey; HF assessment; HCW interview)	Munos et al. 2018 (43) (MICS; HF assessment; HCW interview)			
Health service/intervention	**(1) Partograph to monitor labour**	**(2) Active management of third stage of labour**	**Post-delivery care**	**(1) Obstetric services: readiness**	**(2) Obstetric services: service availability**	**Facility based delivery**	**Obstetric care**	**(1) Delivery care**	**(2) Immediate newborn care**	**Prevention of PPH**	**(1) Labour & delivery: structural quality**	**(2) Labour & delivery: process quality**	**(3) Immediate newborn: structural quality**	**(4) Immediate newborn: process quality**
Target population														
Women who have given birth	Women with live birth in 12mnths prior to survey	Women with live birth in 12mnths prior to survey	Women with a live birth in last 2 yrs	Proportion of recent live births	Proportion of recent live births	Women living in the catchment area of one of the study dispensaries, who were at least 15 years of age and had delivered within 1 yr prior to interview	Women living in the catchment area of one of the study dispensaries, who were at least 15 years of age and had delivered within 1 yr prior to interview	Proportion of women per state with a past-year live birth for each 5-year age group from 20 to 50	Proportion of women per state with a past-year live birth for each 5-year age group from 20 to 50	Women aged 13-49 who had a live birth in 12 mnths prior to survey	Women report a live birth in the 2 yrs preceding the survey	Women report a live birth in the 2 yrs preceding the survey	Women report a live birth in the 2 yrs preceding the survey	Women report a live birth in the 2 yrs preceding the survey
Service contact coverage														
Facility based childbirth	Women reported giving birth in a facility	Women reported giving birth in a facility	Women reported delivered in a health facility	Recent live facility births	Recent live facility births	Women reported delivered in a health facility	Facility based births recorded in facility record	Deliveries in IMSS facilities	Live newborns in IMSS facilities	Women reported institutional delivery & attended by a skilled birth attendant	Women report delivery in a health facility	Women report delivery in a health facility	Women report delivery in a health facility	Women report delivery in a health facility
Input-adjusted coverage														
Inputs: service infrastructure														
Ambulance/Emergency transport					Reported availability and reported functionality of a vehicle with fuel that is routinely available that can be used for emergency transportation or access to a vehicle in near proximity that can be used for emergency transportation	Reported availability: Facility has a functioning vehicle with fuel that is routinely available that can be used for emergency transportation or access to a vehicle in near proximity that can be used for emergency transportation					Facility reported to have a functioning vehicle with fuel that is routinely available that can be used for emergency transportation or access to a vehicle in near proximity that can be used for emergency transportation			
Communication equipment					Observed availability and reported functionality of a shortwave radio or phone	Reported availability: Functioning communication equipment. This will not include private cell phones								

					(landline or cellular)	unless the facility reimburses for cost of phone calls. This will not include payphones outside of the facility.								
Computer with email/internet access						Reported availability: Facility has a functioning computer and has access to email/internet with internet working on the day of the survey.								
Delivery beds					Observed availability of a delivery bed		Delivery table				Delivery bed			
Examination light					Observed availability and reported functionality of a spotlight source (or flashlight)	Items observed and functioning in the main service area: Spotlight source that can be used for patient examinations. A functional flashlight is accepted.	Examination lamp				Observed a functioning spotlight source that can be used for patient examinations in service area or adjacent area. A functional flashlight is accepted.			
Facility register														
Patient toilet clean & water & soap for handwashing														
Power/Electricity					Reported availability of electricity for lights and communication (at a minimum) from any power source, with no break in power for more than 2 h per day during the past 7 d	Reported availability: Facility routinely has electricity for lights and communication (at a minimum) from any power source during normal working hours; there has not been a break in power for more than 2 hours per day during the past 7 days	Electricity							
Private delivery room						Observed availability: Private room or screened								

						off area available in main service area (usually the general outpatient service area), a sufficient distance from sites where providers/clients routinely may be, so that a normal conversation could be held without being overheard, and without the client being observed								
Rooming in														
Sanitation					Reported availability of improved sanitation: flush/pour flush to piped sewer system or septic tank or pit latrine, pit latrine with slab, composting toilet	Observed availability: The toilet/latrine is classified using uniform criteria for improved sanitation promoted by UNICEF. These include the following: Flush/pour flush to piped sewer system or septic tank or pit latrine, pit latrine (ventilated improved pit (VIP) or other) with slab, composting toilet. There is adequate sanitation facilities accessible (unlocked or key available) for clients on premises	Toilet facilities							
Water supply					Observed availability of an improved water source within 500 meters of facility: piped, public tap, standpipe,	Observed availability: Improved water source uses uniform definitions for safe water sources promoted by	Clean water							

					tubewell/bore hole, protected dug well, protected spring, rain water	UNICEF. These include the following: Piped, public tap, standpipe, tubewell/bore hole, protected dug well, protected spring, rain water. NOTE: The type of base for the standpipe or tubewell is not considered for this question. The water source is located inside the facility or within the ground of the facility								
Inputs: Staffing, training & guidelines														
Checklist/job aid						Check-lists and/or job-aids for essential childbirth care. Guidelines observed in service area.					checklist/job aid			
Guidelines: BEmONC											guidelines for BEmONC		guidelines for BEmONC	
Guidelines: CEmONC						Country adapt to which guidelines are required/accepted. Guidelines observed in service area.					guidelines for CEmONC			
Guidelines: essential childbirth care						Guidelines for essential childbirth care. Country adapt to which guidelines are required/accepted. Guidelines observed in service area.					Guidelines for essential childbirth observed in service area. Country adapt to which guidelines are required/accepted			
Guidelines: essential newborn care						Guidelines for essential newborn care. Country adapt to which guidelines are required/accepted.								

						Guidelines observed in service area.								
Guidelines: Integrated Management of pregnancy and childbirth (IMPAC)					Observed availability of guidelines for Integrated Management of pregnancy and childbirth (IMPAC)									
Guidelines: management of preterm labour														
Guidelines: standard precaution						Guidelines for standard precautions. Observed availability anywhere in their facility								
Provider knowledge/skills							Clinical health worker 60-item knowledge test and two clinical vignettes							
Supervision											1. staff supervisions 2. staff with observed supervision			
Training: AMTSL														
Training: CEmOC														
Training: surgery														
Training: clean cord care														
Training: early and exclusive breastfeeding														
Training: Integrated Management of pregnancy and childbirth (IMPAC)					At least one staff member providing the service trained in IMPAC in the last 2-3 years									
Training: KMC														
Training: neonatal resuscitation						At least one staff member providing the service trained in newborn resuscitation using bag and mask in the last two years. Interview								

						response from in-charge of service area day of survey.								
Training: newborn infection and management (inlc. Injectable antibiotics)														
Training: routine labour and delivery care						At least one staff member providing the service trained in essential childbirth care in the last two years (other than training on newborn resuscitation using bag and mask). Interview response from in-charge of service area day of survey.					1.qualified staff 2.trained			
Training: thermal care														
Skilled birth attendant											skilled person 24 hrs			
Inputs: Supplies & commodities														
Amlodipine tablet or alternative calcium channel blocker						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Amoxicillin syrup/suspension or dispersible tablet						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Amoxicillin tablet						Respiratory antibiotic. Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								

Ampicillin powder for injection						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Antibiotic eye ointment					Observed availability of at least one valid unit of antibiotic eye ointment (tetracycline or other) for newborns in service area or where routinely stocked	Antibiotic eye ointment for newborn. Observed in service area OR where routinely stored; in stock with at least one valid.					Antibiotic eye ointment for newborn. Observed in service area OR where routinely stored; in stock with at least one valid.	Eye ointment		
Antibiotics for preterm													Antibiotics for preterm	
Anticonvulsants					Observed availability of at least one valid unit of injectable magnesium sulphate or diazepam in service area or where routinely stocked	Magnesium sulphate 50% injection or alternative strength. Observed in service area OR where routinely stored; in stock with at least one valid.	Magnesium sulfate				Magnesium sulphate 50% injection or alternative strength. Observed in service area OR where routinely stored; in stock with at least one valid			
Storage of infectious waste						Waste receptacle (pedal bin) with lid and plastic bin liner. Observed availability in all three main service areas: general OPD, HIV testing area, and surgery area								
Aspirin cap/tab						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
ATC for mother							Apricitabine for mother							
Beclometasone inhaler						Observed in pharmacy or in area where								

						they are routinely stored, at least one with valid expiration date.								
Beta blocker (e.g.bisoprolol, metoprolol, carvedilol, atenolol)						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Blood glucose						Glucometer and glucometer test strips. Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Blood pressure apparatus						Items observed and functioning in the main service area: Digital BP machine or manual sphygmomanometer with stethoscope	Blood pressure cuff				Digital BP machine or manual sphygmomanometer with stethoscope observed in service area			
Carbamazepine tablet						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Ceftriaxone injection						2nd line injectable antibiotic. Observed in								

						pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Chlorhexidine												Chlorhexidine for the newborn cord		
Clock/timer/watch							Clock							
Cloth to dry/wrap baby												Clean cloths/towels to dry the baby Cloth to wrap the baby		
Corticosteroids													Betamethasone or dexamethasone. Observed available in pharmacy or where they are routinely stored, at least one with valid expiration date.	
Delivery pack OR all the following individual equipment: cord clamp, episiotomy scissors, scissors or blade to cut cord, suture material with needle, and needle holder					Observed availability of at least one delivery pack OR all the following individual equipment: cord clamp, episiotomy scissors, scissors or blade to cut cord, suture material with needle, and needle holder	Delivery pack OR cord clamp, episiotomy scissors, scissors/blade to cut cord, suture material with needle, AND needle holder. Observed availability, reported functionality, and in service area or adjacent area.	Delivery kit				Observed delivery pack OR cord clamp, episiotomy scissors, scissors/blade to cut cord, suture material with needle, AND needle holder in service area or adjacent area			
Delivery pack component: Cord clamps							Cord clamps					Cord ligatures		
Delivery pack component: Sterile scissors or new razor to cut cord												Sterile scissors or new razor blade to cut the cord		

Delivery pack component: Sterile syringes and needles		Health facility with sterile syringes and needles available				Single use — standard disposable or auto-disable syringes. Observed availability anywhere in the facility								
Delivery pack component: Sutures							Sutures							
Diazepam injection						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Enalapril tablet or alternative ACE inhibitor e.g. lisinopril, ramipril, perindopril						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Foetal Stethoscope														
Fluoxetine tablet						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Gauze												Gauze		
Gentamicin injection						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Glibenclamide tablet						Oral treatment type 2 diabetes. Observed in pharmacy or in area where they are routinely stored, at least one with valid								

						expiration date.								
Gloves					Observed availability of latex gloves or equivalent	Latex gloves. If equivalent non latex gloves are available this is acceptable. Observed available in all four main service areas: general OPD, HIV testing area, basic obstetric and newborn care area and surgery area.	Gloves				Sterile latex or equivalent observed in service area	Sterile gloves		
Haemoglobin test kit						This may include colorimeter OR haemoglobin meter OR hemocue. Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.	Haemoglobin test kit							
Haloperidol tablet						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Heat source move to infrastructure?														
HIV diagnostic capacity						RDT kit or ELISA test with ELISA washer, ELISA reader, incubator, specific assay kit. Able to								

						conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Hydralazine							Hydralazine							
Infection control measures in delivery room														
Infection control: Disinfectant							Disinfectant				Disinfectant	Disinfectant		
Infection control: hand rub/disinfectant or delivery room has water and soap						Soap and running water or alcohol based hand rub. Observed in service area.					Soap and running water OR alcohol based hand rub observed in service area			
Infection control: Skin disinfectant					Observed availability of skin disinfectant in service area or where routinely stocked	Skin disinfectant. Observed in service area OR where routinely stored; in stock with at least one valid.					skin disinfectant. Observed in service area OR where routinely stored; in stock with at least one valid			
Infusion set and intravenous fluids					Observed availability of infusion set and intravenous fluids (normal saline or Ringers Lactate or Dextrose 5%)	Normal saline or Ringers Lactate, and Dextrose 5%. Observed in service area OR where routinely stored; in stock with at least one valid.	Intravenous fluids				Normal saline or Ringers Lactate, and Dextrose 5%. Observed in service area OR where routinely stored; in stock with at least one valid.			
Injectable antibiotics					Observed availability of at least one valid unit of broad-spectrum injectable antibiotic (gentamicin, penicillin, or ampicillin or	Broad-spectrum injectable antibiotic treatment of sepsis in mother and newborn-Specific combination-Ampicillin +	Injectable antibiotic for mother				Broad-spectrum injectable antibiotic treatment of sepsis in mother and newborn. Specific combination Ampicillin +		Procaine benzylpenicillin (PBP) or gentamicin and ceftriaxone. Observed available in pharmacy or where they are routinely	

					ceftriaxone) in service area or where routinely stocked	gentamicin OR penicillin + gentamicin OR ceftriaxone OR as per country specific formulation. Observed in service area OR where routinely stored; in stock with at least one valid.					gentamicin OR penicillin + gentamicin OR ceftriaxone OR as per country specific formulation. Observed in service area OR where routinely stored; in stock with at least one valid.		stored, at least one with valid expiration date	
Insulin regular injection						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Malaria diagnostic capacity						RDT kit or smear with microscope, slides, and Wright Giemsa stain. Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Manual vacuum extractor					Observed availability and reported functionality of a manual vacuum extractor	Manual vacuum extractor. Observed availability, reported functionality, and in service area or adjacent area.					Observed manual vacuum extractor in service area or adjacent area			
Measuring cup														

Metformin tablet						Gastroesophageal reflux. Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Neonatal antibiotic							Neonatal antibiotic							
Neonatal bag & mask					Observed availability and reported functionality of a newborn bag and mask	Newborn bag and mask (size 1 for term babies AND size 0 for preterm babies). Observed availability, reported functionality, and in service area or adjacent area.	Neonatal ambu-bag and mask				Observed newborn bag and mask (size 1 for term babies AND size 0 for preterm babies) in service area or adjacent area			
Nevirapine for baby							Nevirapine for baby							
Nevirapine for mother							Nevirapine for mother							
Omeprazole tablet or alternative such as pantoprazole, rabeprazole						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Oral rehydration solution						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Partograph	Facility with blank partographs in stock				Observed availability of blank partographs	Blank partograph. Observed in service area.	Partographs				Blank partographs in service area			
Safe final disposal of infectious wastes						Safe final disposal of infectious wastes includes incineration, open burning in protected area, dump without								

						burning in protected area, or remove offsite with protected storage. If method is incineration, incinerator functioning and fuel available. Observed final disposal/holding site for infectious wastes and verify no unprotected waste is observed.								
Safe final disposal of sharps						Safe final disposal of sharps includes incineration, open burning in protected area, dump without burning in protected area, or remove offsite with protected storage. If method is incineration, incinerator functioning and fuel available. Observed final disposal/holding site for sharps and verify no unprotected sharps are observed.								
Salbutamol inhaler						Chronic asthma attacks. Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								

Scale						Items observed and functioning in the main service area: Adult scale & child scale with weight gradation minimum 250 grams. A digital standing scale where adult holds child and gradations go to 250 grams is acceptable	Infant and/or child scale				Infant weighing scale observed in service area			
Sharps box/Appropriate storage of sharps waste						A puncture-resistant, rigid, leak resistant container designed to hold used sharps safely during collection, disposal and destruction. Sharps containers should be made of plastic, metal, or cardboard and have a lid that can be closed. Sharps containers should be fitted with a sharps aperture, capable of receiving syringes and needle assemblies of all standard sizes, together with other sharps. Boxes must be clearly marked with the international biohazard warning not less than 50mm diameter, printed in black or red								

						on each of the front and back faces of the box. Observed availability in all three main service areas: general OPD, HIV testing area, and surgery area.								
Simvastatin tablet or other statin e.g. atorvastatin, pravastatin, fluvastatin						High cholesterol. Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Stainless steel bowl							Stainless steel bowls							
Sterilisation equipment					Observed availability and reported functionality of either a dry heat sterilizer or an autoclave	This is usually either a dry heat sterilizer or an autoclave. If the machine is not electric, then make sure that the heat source is available and (If relevant) functioning (e.g., wood or gas is present for the autoclave). Observed availability anywhere in the facility reported functionality.	Sterilization equipment								
Stethoscope						Items observed and functioning in the main service area: stethoscope	Stethoscope							
Suction apparatus					Observed availability and reported functionality of suction bulb or electric suction pump or suction catheter	Suction bulb (single use or sterilisable multi-use) or electric suction pump AND suction catheter for suctioning newborn. Observed availability,	Mucus suction				Observed to have suction bulb (single use or sterilisable multi-use) or electric suction pump AND suction catheter for suctioning newborn in			

						reported functionality, and in service area or adjacent area.					service area or adjacent area			
Surface disinfectant						Chlorine-based or other country specific used for environmental disinfection								
Syphilis rapid test						RDT kit. Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Thermometer						Items observed and functioning in the main service area: thermometer	Thermometer							
Thiazide (e.g. hydrochlorothiazide)						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Urine glucose dipstick						Dipsticks for urine glucose (with valid expiration date). Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-								

						site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Urine protein dipstick						Dipsticks for urine protein (with valid expiration date). Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Urine test for pregnancy						RDT kit. Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. These may be in a laboratory or in the service area where the test is conducted.								
Uterotonic		Facility with oxytocin or ergometrine available			Observed availability of at least one valid unit of injectable uterotonic (oxytocin or other) in service area or where routinely stocked	Oxytocin. Observed in service area OR where routinely stored; in stock with at least one valid.	Uterotonic				Oxytocin. Observed in service area OR where routinely stored; in stock with at least one valid.	Oxytocin, Ergometrine, Misoprostol, Syntometrine		

Vacuum aspirator or D&C kit					Observed availability and reported functionality of a vacuum aspirator or D&C kit	Vacuum aspirator or D&C kit (with speculum). Observed availability, reported functionality, and in service area or adjacent area.					Observed vacuum aspirator or D&C kit (with speculum) in service area or adjacent area			
Zinc sulphate tablets, dispersible tablets or syrup						Observed in pharmacy or in area where they are routinely stored, at least one with valid expiration date.								
Inputs: service availability														
CEmOC: blood transfusion				Reported performance of blood transfusion in the three months before the health facility survey										
CEmOC: c-section				Reported performance of caesarean section in the three months before the health facility survey										
EmOC: Administers antibiotic				Reported performance of parenteral antibiotics in the three months before the health facility survey		Parenteral administration of antibiotics for mothers	Parenteral antibiotics provided in last 3 months				Facility offering parenteral administration of antibiotics for mothers			
EmOC: Assisted/instrumental vaginal delivery				Reported performance of assisted vaginal delivery in the three months before the health facility survey		Assisted vaginal delivery					Facility offering assisted vaginal delivery			
EmOC: Corticosteroids						Facility offers: Corticosteroids in preterm labour								
EmOC: Manual removal of placenta				Reported performance of manual removal of placenta in		Facility offers: Manual removal of placenta	Manual removal of placenta provided in last 3 months				Facility offering manual removal of placenta			

				the three months before the health facility survey										
EmOC: Manual removal of retained products				Reported performance of manual removal of retained products in the three months before the health facility survey		Facility offers: Manual removal of retained products	Removal of retained products of conception provided in the last 3 months				Facility offering manual removal of retained products			
EmOC: Parenteral administration of anticonvulsants for hypertensive disorders of pregnancy				Reported performance of parenteral anticonvulsants in the three months before the health facility survey		Parenteral administration of anticonvulsants	Parenteral anticonvulsants provided in the last 3 months							
EmOC: Parenteral uterotonic for haemorrhage				Reported performance of parenteral uterotonics in the three months before the health facility survey		Facility offers: Routine administration of oxytocin injection immediately after birth to all women for the prevention of post-partum haemorrhage	Uterotonic provided in the last 3 months				Facility offers routine administration of oxytocin injection immediately after birth to all women for the prevention of postpartum haemorrhage			
Newborn signal function: baby weigh														
Newborn signal function: Breastfeeding						Facility offers: Immediate and exclusive breastfeeding							Facility offering immediate and routine breastfeeding	
Newborn signal function: cord care						Facility offers hygienic cord care: Cut with sterile item and apply disinfectant to tip and stump, and no application of other substances							Service availability: facility offering hygienic cord care. Cut with sterile item and apply disinfectant to tip and stump, and no application of other substances	
Newborn signal function: Drying and wrapping						Facility offers: Thermal protection (drying baby immediately after birth and wrapping)							Facility offers Thermal protection (drying baby immediately after birth and wrapping)	

Newborn signal function: KMC for LBW babies						Facility offers: KMC (Kangaroo mother care) for premature/very small babies							Facility offering KMC for LBW babies	
Newborn signal function: Neonatal resuscitation				Reported performance of neonatal resuscitation in the three months before the health facility survey		Facility offers: Neonatal resuscitation with bag and mask	Newborn resuscitation with bag and mask provided in the last 3 months						Facility offering neonatal resuscitation with bag and mask	
Newborn signal function: PROM						Facility offers: Antibiotics for preterm or prolonged PROM to prevent infection								
Newborn signal function: sepsis management						Facility offers: Injectable antibiotics for neonatal sepsis								
Newborn signal function: skin-to-skin														
Newborn: BCG vaccine														
Newborn: polio vaccine														
Newborn: postnatal check														
Partograph						Facility offers: Monitoring and management of labour using partograph					Facility offers monitoring and management of labour using partograph			
Vitamin A														
Intervention coverage														
Administer prophylaxis for eyes/apply eye ointment														HCW report at last delivery: administer prophylaxis for the eyes
AMSTL: Active management of 3rd stage labour										SBA reported undertaking active management of third stage of labour at last birth attended				

AMSTL: Administers uterotonic/Parenteral uterotonic		HCW reported giving an oxytocic agent during the last delivery attended								SBA reported undertaking administration of prophylactic uterotonics to prevent post-partum haemorrhage during last birth attended				
AMSTL: Controlled cord traction														
AMSTL: Prepares uterotonic														
AMSTL: Uterine massage														
Apgar score							Average of all deliveries recorded in the facility delivery Apgar score							
Baby weighed							Average of all deliveries recorded in the facility delivery baby weighed							HCW report at last delivery: weigh the baby
Breastfeeding			Observation of breastfeeding initiation within 1 hour of delivery				Average of all deliveries recorded in the facility delivery baby breastfed within 1h							HCW report at last delivery: initiate breastfeeding within the first hour
Check breathing														HCW report at last delivery: ensure the baby is breathing
Check cord care														
Clean baby's mouth before shoulder comes out														HCW report at last delivery cleans baby's mouth before shoulder comes out
Clean baby's mouth, face and nose														HCW report at last delivery: clean baby's

														mouth, face and nose
Cord care														HCW report at last delivery: care for the umbilical cord
Cord care: alcohol														HCW report at last delivery: cord care alcohol
Cord care: chlorhexidine														HCW report at last delivery: apply chlorhexidine
Cord care: cord wrapped in dry cloth														HCW report at last delivery: cord wrapped in dry cloth
Cord care: tie or clamp cord after 2/3 mins														
Disposable delivery kit used														
Breastfeeding														
EmNC: Dexamethasone to mother for premature labour														
EmNC: Injectable antibiotics for newborn sepsis														
EmNC: Intravenous fluids for newborns														
EmNC: Kangaroo mother care														
EmNC: Neonatal resuscitation														HCW report at last delivery: resuscitation open the airways, clean the mouth/use suction device, stimulating/drying/wrapping the baby, use the ambu bag, heart massage
EmOC: Assisted/instrumental vaginal delivery														
EmOC: Blood transfusions														
EmOC: Caesarean sections														

EmOC: Manual removal of placenta														
EmOC: Manual removal of retained products														
EmOC: Parenteral antibiotics or antibiotics for maternal infection														
EmOC: Parenteral anticonvulsants														
EmOC: Parenteral oxytocin for haemorrhage														
Examine perineal and vaginal lacerations														
Examine placenta/assesses completeness of placenta and membranes														
HIV test							Average of all deliveries recorded in the facility delivery HIV test							
Infection prevention/wash hands before examination														
Iron folate tablets														
Palpitates uterus 15 min after delivery														
Thermal care: Baby dried/wrapped														HCW report at last delivery: Ensure the baby is dry
Thermal care: Baby kept dry/warm														HCW report at last delivery: ensure baby is kept warm
Thermal care: Bathing delayed														
Thermal care: Skin-to-skin			Observation of newborn placed skin-to-skin											
Wear sterile gloves for vaginal examination														
Process quality-adjusted coverage														
Quality: process														
Asks about headaches, bleeding														
Delivered on a clean floor/bed														
Maternal blood pressure							Average of all deliveries recorded in the facility delivery maternal					HCW report at last delivery: monitor maternal		

							blood pressure					blood pressure		
Maternal pulse												HCW report at last delivery: monitor maternal pulse		
Maternal temperature												HCW report at last delivery: monitor maternal temperature		
Monitor colour of amniotic fluid												HCW report at last delivery: Monitor colour of amniotic fluid		
Monitor degree of molding												HCW report at last delivery: Monitor degree of molding		
Monitor descent of head												HCW report at last delivery: Monitor descent of the head		
Monitor dilation of cervix												HCW report at last delivery: Monitor dilation of the cervix		
Monitor foetal heartbeat												HCW report at last delivery: Monitor foetal heartbeat		
Monitor labour progress												HCW report at last delivery: Monitor labour progress		
Monitor uterine contractions												HCW report at last delivery: monitor uterine contraction		
Observe baby colour														HCW report at last delivery: Observe for colour
Partograph	HCW reported using a partograph during the last						Average of all deliveries recorded in the facility delivery partographs							

	delivery attended													
Postnatal check/Initial assessment child's health														HCW report at last delivery: evaluate/examine the newborn within the first hour
Postpartum check														
Rooming in			Observation keeping the mother and newborn in the same room											
Quality: interpersonal														
Explain what will happen in labour														
Support person at birth														
User-adherence coverage														
Outcomes-adjusted coverage														
Death								Proportion of deliveries without complications or death	Proportion of live births reaching 28 days without death due to respiratory infection, noso comial infection or sepsis					

TABLE NOTE: * extraction based on SARA general service readiness indicators & specific availability & readiness indicators for basic obstetric and newborn care. Authors state used all 70 binary general and delivery-related SARA indicators; we identified 86 in extraction and not possible to determine which were used by the authors.

Table S4 continued….

Study (data sources)	Nesbitt et al. 2013 (54) (Surveillance data; HF assessment)	Nguhiu et al. 2017 (40) (DHS; SPA)	Nguyen et al. 2021 (44) (DHS, SPA)	Okawa et al. 2019a (49) (HH survey)	Okawa et al. 2019b (46) (HH survey)	Sharma et al. 2017 (41) (SPA, DHS, the Oxford Poverty and Human Development Initiative, observations)		Shibanuma et al. 2018 (58) (HH survey)	Wang et al. 2019 (36) (DHS; SPA)	Willey et al. 2018 (56) (HH survey; HF assessment)
Health service/intervention	**Intrapartum & immediate newborn care**	**Skilled delivery & perinatal care**	**Birth care**	**Peripartum care**	**Peripartum care**	**(1) Delivery care: inputs**	**(2) Delivery care: processes of care**	**Facility delivery**	**Facility delivery**	**Basic emergency obstetric care**
Target population										
Women who have given birth	Live births in study area	Women 15–49 years old with at least one child under 5 years	Women 15–49 years old with a live birth in the 3 years preceding the survey	Women between 6 wks -12 mnths postpartum	Women aged 15-49 yrs delivered in 2 yrs prior to survey	Total population at county level	Total population at county level	Women aged 15-49 yrs delivered live or stillbirth in 2 yrs prior to survey	Number of live births in 2yrs prior to survey	Women aged 15-49 years who reported a live birth in the 2yrs prior to survey
Service contact coverage										
Facility based childbirth	Facility delivery	Most recent birth, reported attendance by a skilled health provider (doctor, nurse or midwife)	Most recent birth, reported delivery in a health facility	Delivery at a healthcare facility with the assistance of skilled care providers	Delivery with assistance of skilled healthcare providers at a healthcare facility	Population living with 5km of facility	Population living with 5km of facility	Delivered at a health facility and assisted by a skilled birth attendant	Facility-based live births in 2 yrs preceding survey	Women reported place of birth & attended by SBA
Input-adjusted coverage										
Inputs: service infrastructure										
Ambulance/Emergency transport						Ambulance			The facility had a functioning ambulance or other vehicle for emergency transport that was stationed at the facility and had fuel available on the day of the assessment, or the facility has access to an ambulance or other vehicle for emergency transport that is stationed at another facility or that operates from another facility.	
Communication equipment						Communication				
Computer with email/internet access										
Delivery beds						Delivery beds			At least one delivery bed available and observed in delivery area.	
Examination light						Exam light			Examination light (flashlight okay) available, observed, and functioning in delivery area.	
Facility register		HCW report and observed register for delivery clients present								

Patient toilet clean & water & soap for handwashing	Observed patient toilet is clean & has water and soap for handwashing									
Power/Electricity						Electricity			Facility is connected to a central power grid and there has not been an interruption in power supply lasting for more than two hours at a time during normal working hours in the seven days before the assessment, or the facility had a functioning generator with	Source of electricity 24 hr/day available on the day of the survey
Private delivery room						Private delivery room				
Rooming in		HCW report rooming in mother/newborn								
Sanitation	Patient toilet exists								Facility has a functioning flush or pour-flush toilet, a ventilated improved pit latrine, or composting toilet.	
Water supply	Reported clean water source					Water			Facility has an improved water source available. For most countries, this means that water is piped into the facility or onto facility grounds, or else water comes from a public tap or standpipe, a tube well or borehole, a protected dug well, protected spring, rain water, or bottled water, and the outlet from this source is within 500 meters of the facility	Source of running water 24/hr available on the day of the survey
Inputs: Staffing, training & guidelines										
Checklist/job aid										
Guidelines: BEmONC			Guidelines on basic birth care (BEmONC)							
Guidelines: CEmONC			Guidelines on comprehensive birth care (CEmONC)						CEmOC guidelines available in delivery area	
Guidelines: essential childbirth care										

Guidelines: essential newborn care										
Guidelines: Integrated Management of pregnancy and childbirth (IMPAC)									Integrated Management of Pregnancy and Childbirth (IMPAC) guidelines available in delivery area	
Guidelines: management of preterm labour									Guidelines for management of preterm labour available in delivery area	
Guidelines: standard precaution									Guidelines for standard precautions available in delivery area	
Provider knowledge/skills										
Supervision									At least half of interviewed providers reported being personally supervised at least once during the 6 months preceding the survey	
Training: AMTSL									At least one provider of delivery/newborn care in facility received training in AMTSL in the past 24 months	
Training: CEmOC									At least one provider of delivery/newborn care in facility received training in IMPAC (presented as reported potentially author meant CEmOC) in the past 24 months	
Training: surgery	≥ 1 doctor conducting caesarean section									
Training: clean cord care									At least one provider of delivery/newborn care in facility received training in cord care in the past 24 months	
Training: early and exclusive breastfeeding									At least one provider of delivery/newborn care in facility received training in early and exclusive breastfeeding in the past 24 months	
Training: Integrated Management of			Staff with any training on IMPACT						At least one provider of delivery/newborn	

pregnancy and childbirth (IMPAC)									care in facility received training in IMPAC in the past 24 months	
Training: KMC									At least one provider of delivery/newborn care in facility received training in KMC in the past 24 months	
Training: neonatal resuscitation	≥ 1 health professional trained in neonatal resuscitation								At least one provider of delivery/newborn care in facility received training in neonatal resuscitation in the past 24 months	
Training: newborn infection and management (inlc. Injectable antibiotics)									At least one provider of delivery/newborn care in facility received training in newborn infection management (including injectable antibiotics) in the past 24 months	
Training: routine labour and delivery care						HCW trained in delivery care			At least one provider of delivery/newborn care in facility received training in routine care during labour and normal vaginal delivery in the past 24 months	
Training: thermal care									At least one provider of delivery/newborn care in facility received training in thermal care in the past 24 months	
Skilled birth attendant	Human resource capacity for 24 hour service availability: ≥3 skilled health professionals employed					24-hour delivery care			Provider of delivery care available on-site or on-call 24 hours/day, with observed duty schedule	
Inputs: Supplies & commodities										
Amlodipine tablet or alternative calcium channel blocker										
Amoxicillin syrup/suspension or dispersible tablet										
Amoxicillin tablet										
Ampicillin powder for injection										
Antibiotic eye ointment									Tetracycline eye ointment for	

									newborn available in delivery area and at least one dose valid.	
Antibiotics for preterm										
Anticonvulsants	Observed Diazepam or Magnesium Sulfate					Magnesium sulfate			Magnesium sulphate available in delivery area with at least one dose valid.	Essential drugs for management of complications in mothers and babies available: parenteral anticonvulsants
Storage of infectious waste										
Aspirin cap/tab										
ATC for mother										
Beclometasone inhaler										
Beta blocker (e.g.bisoprolol, metoprolol, carvedilol, atenolol)										
Blood glucose										
Blood pressure apparatus	Reported sphygmomanometer available		Manual or digital BP apparatus			Blood pressure cuff			Manual or digital blood pressure apparatus observed and functioning in delivery area.	Commodities to monitor and manage labour available on day of survey: blood pressure cuff
Carbamazepine tablet										
Ceftriaxone injection										
Chlorhexidine									Chlorhexidine solution (4%) for umbilical cord cleaning available in delivery area, with at least one dose valid.	
Clock/timer/watch	Observed clock									Commodities to monitor and manage labour available on day of survey: timer
Cloth to dry/wrap baby						Towels				
Corticosteroids	Observed Dexamethasone								Hydrocortisone observed at the facility and at least one dose valid.	
Delivery pack OR all the following individual equipment: cord clamp, episiotomy scissors, scissors or blade to cut cord, suture material with needle, and needle holder									Delivery pack OR cord clamp, episiotomy scissors, scissors/blade to cut cord, suture material with need, AND needle holder all available in delivery area.	
Delivery pack component: Cord clamps						Umbilical cord clamps				Commodities for hygienic core care available on day of survey: cord tie

Delivery pack component: Sterile scissors or new razor to cut cord						blade				Commodities for hygienic core care available on day of survey: Sterile cord cutter
Delivery pack component: Sterile syringes and needles	Observed small syringes/needs for babies									
Delivery pack component: Sutures										
Diazepam injection										
Enalapril tablet or alternative ACE inhibitor e.g. lisinopril, ramipril, perindopril										
Foetal Stethoscope	Observed fetoscope									Commodities to monitor and manage labour available on day of survey: foetal stethoscope
Fluoxetine tablet										
Gauze										
Gentamicin injection										
Glibenclamide tablet										
Gloves									Disposable latex gloves observed in delivery area.	Commodities for infection prevention available on day of survey: disposable gloves
Haemoglobin test kit										
Haloperidol tablet										
Heat source move to infrastructure?						Heat source				
HIV diagnostic capacity										
Hydralazine										
Infection control measures in delivery room						Infection control measures in delivery room				
Infection control: Disinfectant										Commodities for infection prevention available on day of survey: disinfectant
Infection control: hand rub/disinfectant or delivery room has water and soap	Observed sink with soap for hand washing								Hand-washing soap and running water or hand disinfectant available and observed in delivery area.	Commodities for infection prevention available on day of survey: soap

Infection control: Skin disinfectant									Skin disinfectant available for newborns in delivery area.	
Infusion set and intravenous fluids	Reported availability of intravenous fluids with infusion sets								IV solution with infusion set available in delivery area with at least one set valid.	
Injectable antibiotics	Reported availability of ampicillin or gentamicin								Injectable antibiotics observed in delivery area (i.e., at “service site”) and at least one dose valid.	Essential drugs for management of complications in mothers and babies available: parenteral antibiotics for maternal infection and newborn sepsis
Insulin regular injection										
Malaria diagnostic capacity										
Manual vacuum extractor									Manual vacuum extractor available, observed, and functioning in the delivery area.	
Measuring cup	Observed graduated measuring cup									
Metformin tablet										
Neonatal antibiotic										
Neonatal bag & mask	Observed bag + mask for baby					Newborn bag & mask			Newborn bag and mask (AMBU bag and mask) available, observed, and functioning in the delivery area.	Bag & mask available on day of survey
Nevirapine for baby										
Nevirapine for mother										
Omeprazole tablet or alternative such as pantoprazole, rabeprazole										
Oral rehydration solution										
Partograph	Observed correctly filled partograph					Partographs			Partograph available, observed, and functioning in delivery area.	
Safe final disposal of infectious wastes										
Safe final disposal of sharps										
Salbutamol inhaler										
Scale	Reported weighing scale		Infant scale						Infant scale observed and functioning in delivery area.	

Sharps box/Appropriate storage of sharps waste										Commodities for infection prevention available on day of survey: sharps box
Simvastatin tablet or other statin e.g. atorvastatin, pravastatin, fluvastatin										
Stainless steel bowl										
Sterilisation equipment									Facility reports that some instruments are processed in the facility and the facility has a functioning electric dry heat sterilizer, a functioning electric autoclave, or a non-electric autoclave with a functioning heat source available somewhere in the facility.	Commodities for infection prevention available on day of survey: sterilizer
Stethoscope						Stethoscope				
Suction apparatus									Suction apparatus (mucus abstractor) available, observed, and functioning in the delivery area.	
Surface disinfectant										
Syphilis rapid test										
Thermometer										Commodities to monitor and manage labour available on day of survey: thermometer
Thiazide (e.g. hydrochlorothiazide)										
Urine glucose dipstick										
Urine protein dipstick										Commodities to monitor and manage labour available on day of survey: urine protein dipstick
Urine test for pregnancy										

Uterotonic	Observed oxytocin					Injectable oxytocic			Oxytocin observed in delivery area with at least one dose valid.	Essential drugs for management of complications in mothers and babies available on day of survey: parenteral oxytocics for haemorrhage and uterotonics for active management of the third stage of labour
Vacuum aspirator or D&C kit									Vacuum aspirator or D&C kit available, observed, and functioning, in the delivery area.	
Zinc sulphate tablets, dispersible tablets or syrup										
Inputs: service availability										
CEmOC: blood transfusion									Facility performed blood transfusion at least once during the three months before the assessment (incorporate the availability of equipment and materials for performing the service)	
CEmOC: c-section									Facility performed caesarean section at least once during the three months before the assessment (incorporate the availability of equipment and materials for performing the service)	
EmOC: Administers antibiotic									Facility performed parenteral administration of antibiotics at least once during the three months before the assessment	
EmOC: Assisted/instrumental vaginal delivery									Facility performed assisted vaginal delivery at least once during the three months before the assessment	
EmOC: Corticosteroids										
EmOC: Manual removal of placenta									Facility performed manual removal of placenta at least once during the three months before the assessment	

EmOC: Manual removal of retained products									Facility performed removal of retained products at least once during the three months before the assessment	
EmOC: Parenteral administration of anticonvulsants for hypertensive disorders of pregnancy									Facility performed parenteral administration of anticonvulsants for hypertensive disorders of pregnancy at least once during the three months before the assessment	
EmOC: Parenteral uterotonic for haemorrhage									Facility performed parenteral administration of uterotonic drugs/oxytocin at least once during the three months before the assessment	
Newborn signal function: baby weigh		HCW report facility routinely weigh the newborn immediately								
Newborn signal function: Breastfeeding									Facility reported breast feeding in 1st hour is routinely practiced	
Newborn signal function: cord care										
Newborn signal function: Drying and wrapping		HCW report facility routinely dries and wraps newborn to keep them warm							Facility reported drying and wrapping newborns is routinely practiced	
Newborn signal function: KMC for LBW babies		HCW report facility practice kangaroo mother care								
Newborn signal function: Neonatal resuscitation									Facility performed neonatal resuscitation at least once during the three months before the assessment	
Newborn signal function: PROM										
Newborn signal function: sepsis management										
Newborn signal function: skin-to-skin									Facility reported skin-to-skin is routinely practiced	
Newborn: BCG vaccine		HCW report facility routinely gives newborn BCG prior to discharge								

Newborn: polio vaccine		HCW report facility routinely give newborn oral polio vaccine prior to discharge								
Newborn: postnatal check		HCW reports facility routinely completes exam of newborn performed before discharge								
Partograph										
Vitamin A		HCW report facility routinely vitamin A given to mother								
Intervention coverage										
Administer prophylaxis for eyes/apply eye ointment	Report always apply eye ointment to the baby's eyes after delivery									
AMSTL: Active management of 3rd stage labour										
AMSTL: Administers uterotonic/Parenteral uterotonic	Reports always administering injection of oxytocin within 1 minute of delivery						Administer uterotonic correctly			
AMSTL: Controlled cord traction	Reports always performing controlled cord traction									
AMSTL: Prepares uterotonic							Prepare uterotonic drug			
AMSTL: Uterine massage	Reports always undertaking uterine massage									
Apgar score										
Baby weighed	Reports always weigh baby after delivery			Women reported birth weight measured						
Breastfeeding	Reports always initiating breastfeeding within 1 hr of delivery			Women reported breast feeding initiated <30 min	Women reported breast feeding initiated <30 min		Mother initiates breastfeeding within 1 hour	Women reported breast feeding initiated within 1 hr of delivery		
Check breathing										
Check cord care										
Clean baby's mouth before shoulder comes out										

Clean baby's mouth, face and nose										
Cord care										
Cord care: alcohol										
Cord care: chlorhexidine										
Cord care: cord wrapped in dry cloth										
Cord care: tie or clamp cord after 2/3 mins							Tie or clamp cord after 2/3 minutes			
Disposable delivery kit used				Women reported disposable delivery kit used						
Breastfeeding	Report teaching mother to express milk and feed with spoon and cup if baby unable to breastfeed									
EmNC: Dexamethasone to mother for premature labour	Report performing dexamethasone to mother for premature labour									
EmNC: Injectable antibiotics for newborn sepsis	Report performing injectable antibiotics for newborn sepsis									
EmNC: Intravenous fluids for newborns	Report performing intravenous fluids for newborns									
EmNC: Kangaroo mother care	Report teaching mother skin-to-skin or KMC for LBW babies									
EmNC: Neonatal resuscitation	Report performing newborn resuscitation with bag & mask						Prepare newborn bag & mask			
EmOC: Assisted/instrumental vaginal delivery	Report performing instrumental delivery									
EmOC: Blood transfusions	Report performing blood transfusion									
EmOC: Caesarean sections	Report performing caesarean section									
EmOC: Manual removal of placenta	Report performing manual removal of placenta									
EmOC: Manual removal of retained products	Report performing manual removal of retained products of conception									
EmOC: Parenteral antibiotics or antibiotics for maternal infection	Report performing parenteral antibiotic									

EmOC: Parenteral anticonvulsants	Report performing: parenteral anticonvulsants									
EmOC: Parenteral oxytocin for haemorrhage	Report performing parenteral oxytocin									
Examine perineal and vaginal lacerations							Examine for perineal & vaginal lacerations			
Examine placenta/assesses completeness of placenta and membranes							Examine placenta			
HIV test										
Infection prevention/wash hands before examination	Reports always using measures of infection prevention during delivery						Wash hands before any examination			
Iron folate tablets										
Palpitates uterus 15 min after delivery							Palpate uterus 15 min after delivery			
Thermal care: Baby dried/wrapped	Reports always dry baby immediately after delivery			Women reported newborn body dried	Women reported newborn body dried		Dry newborn immediately			
Thermal care: Baby kept dry/warm										
Thermal care: Bathing delayed	Reports always delaying bathing for at least 6 hours after delivery			Women reported first bathing of newborn after 6 hours						
Thermal care: Skin-to-skin	Reports always place baby on mother's abdomen after delivery			Women reported skin-to-skin contact	Women reported skin-to-skin contact		Place newborn skin-to-skin if baby breathing	Women reported skin-to-skin contact		
Wear sterile gloves for vaginal examination							Wear sterile gloves for vaginal examination			
Process quality-adjusted coverage										
Quality: process										
Asks about headaches, bleeding							Asks re headaches. Bleeding			
Delivered on a clean floor/bed				Women reported delivered on a clean floor/bed						
Maternal blood pressure	Reports always measuring blood pressure						Take blood pressure			
Maternal pulse							Take mother's pulse			
Maternal temperature										
Monitor colour of amniotic fluid										
Monitor degree of molding										
Monitor descent of head										
Monitor dilation of cervix										

Monitor foetal heartbeat										
Monitor labour progress										
Monitor uterine contractions										
Observe baby colour										
Partograph	Facility reports always monitoring labour with partograph						Initiate use of partograph			
Postnatal check/Initial assessment child's health										
Postpartum check							Take mother's vital signs 15 min after delivery			
Rooming in										
Quality: interpersonal										
Explain what will happen in labour							Explain what will happen in labour			
Support person at birth	Report that woman can choose to have delivery companion									
User-adherence coverage										
Outcomes-adjusted coverage										
Death										

Table S5 Care of sick newborns

Study (data sources)	Murphy et al. 2018 (38) (HF assessment; medical records)
Health service	**Inpatient neonatal care**
Target population	
	Number of newborns requiring care; estimated by applying the rate of live births requiring inpatient services (183 per 1000 live births) to the total number of live births in the study region between mid-2014 to mid-2015
Service contact	
	Total number of neonatal admissions to INC facilities
Input-adjusted coverage	
Inputs: service infrastructure	
Power/Electricity	Consistent power (outages <monthly) or generator serving NBU
Heat source	Heating in NBU
Water supply	Running water
Inputs: Supplies & commodities	
Laboratory services	1. Minimum package of care: i. Open 24/7 ii. Test for haemoglobin iii. Test for bilirubin (blood test) iv. Glucose tests v. Blood grouping and cross match vi. Electrolytes (sodium / potassium) 2. Blood bank 3. Blood slide microscopy for malaria parasites 4. Test for direct Coombs test 5. Urea or creatinine 6. Liver function tests (enzymes e.g. AST/ALT) 7. Microscopy & culture: Pus swab and urine culture 8. CSF microscopy 9. Coagulation profile 10. Blood culture ability
Hygiene	1. Cleaning/disinfectant supplies 2. Sharps disposed in a special container 3. Clean gloves available 4. Separate clinical and non-clinical waste 5. Sinks with soap and water for hand-washing 6. Mother has access to running water 7. Alcohol hand rub

Safe delivery equipment and drugs for mother	Equipment available on the ward and working on the day of the visit 1. Thermometer 2. Sterile syringes 3. Sterile needles 4. Sterile vaginal examination packs 5. Sterile delivery set (complete) 6. A stethoscope 7. Amnicots/sterile Kocker's forceps for artificial rupture of membrane 8. Urine dipstick kits/strips 9. Urinary catheters 10. Vacuum (such as Kiwi) for assisted vaginal delivery 11. Manual vacuum aspirator (MVA) 12. Long gloves for manual removal of placenta 13. Guedel airways – these should be a full range of sizes 14. Bag Valve Mask (BVM) device: adult size bag and mask 15. Oxygen source (any and working) 16. Nasal catheters/prongs 17. Oxygen face –masks (with and without reservoir bags) 18. Oxygen flow regulators 19. Laryngoscope 20. Laryngoscope blades (straight, curved, and different sizes) 21. Endotracheal tubes (of different sizes) 22. IV fluid giving sets 23. Blood giving set 24. Adult IV cannula 25. Blood pressure monitor (any and working) Drugs available on the ward or accessible within five minutes without administrative barriers 1. Adrenaline 2. Magnesium sulphate 3. Lasix 4. Digoxin 5. Morphine 6. Oxytocin 7. Dexamethasone 8. Prostaglandin F2 alpha 9. Calcium gluconate 10. Penicillin 11. Gentamicin 12. Ceftriaxone/Cefuroxime
Neonatal resuscitation equipment	Available on the ward and working on the day of the visit 1. Thermometer 2. Weighing scales 3. Sterile syringes 4. Sterile needles 5. Warm dry towels for dying and wrapping the newborn 6. Sterile cord clamp 7. Sterile scissors 8. A firm stable surface for placing the newborn for resuscitation (where warmth can be maintained) 9. An overhead light source above the surface for resuscitation 10. A clock in view or reach of surface for resuscitation 11. A stethoscope 12. Suction tubes/catheters 13. Suction Machine 14. Guedel airways – these should be a full range of sizes 15. Bag Valve Mask (BVM) devices: bag size 500 ml or 750 ml, that are in working order with newborn face masks (sizes 0 and 1) 16. Oxygen source (any and working) 17. Nasal catheters/prongs 18. Oxygen face –masks (with and without reservoir bags) 19. Oxygen flow regulators 20. Warming equipment-working radiant heaters

Essential ward equipment in the NBU for treatment and diagnostic procedures	Available on the ward and working on the day of the visit 1. Thermometer 2. Weighing scales 3. Sterile syringes 4. Sterile needles 5. A stethoscope 6. Suction tubes/catheters 7. Suction Machine 8. Guedel airways – these should be a full range of sizes 9. Bag Valve Mask (BVM) devices: bag size 500 ml or 750 ml, that are in working order with newborn face masks (sizes 0 and 1) 10. Oxygen source (any and working) 11. Nasal catheters/prongs 12. Oxygen face –masks (with and without reservoir bags) 13. Oxygen flow regulators 14. Warming equipment-working radiant heaters 15. Kangaroo mother care wraps 16. Phototherapy equipment 17. Eye protection for phototherapy 18. Blood transfusion giving set
IV fluid and feeds in the NBU	1. Feeding cups for giving expressed breast milk 2. IV fluid burette 3. Infusion set / adult IV fluid set 4. Paediatric cannula 5. Nasogastric tube (FG6 or 8 or other) 6. glucose 10% 7. normal saline IV or ringers lactate 8. term formula
NBU drugs	Available if they were on the ward or accessible within five minutes without administrative barriers. * considered available if on the ward or available within the facility and within 2 hours of request 1. Vitamin K 2. Nevirapine solution 3. Prophylactic tetracycline eye ointment* 4. Phenobarbitone (injection) 5. Phenytoin (injection) * 6. Aminophylline* 7. Penicillin (injection) 8. Gentamicin or Amikacin 9. Ampicillin / Cloxacillin (injection) * 10. Oral Cloxacillin * 11. Oral erythromycin* 12. Metronidazole (injection) * 13. Ceftriaxone or cefotaxime* 14. Ferrous Fumarate suspension* 15. Folate drops* 16. Multivitamin syrup/drops* 17. Intravenous (Anti-D) immunoglobulin (for rhesus disease) *
Intervention coverage	
Appropriate antibiotic prescription	Dose of gentamicin and/or penicillin as per national guidelines, allowing for ±20% margin of error
Correct oxygen prescription	Correct route and prescribed to patients requiring oxygen treatment as per recorded signs and symptoms
Correct fluids and feeds volume	As per national guidelines, allowing for ±20% margin of error
Process quality-adjusted coverage	
Quality: process of care	
Documentation of newborn characteristics	Document 9 characteristics: age, sex, mode of delivery, weight, gestational age, Apgar score at 5 min, HIV status, diagnosis, outcome

Documentation of signs and symptoms	Signs (evaluation on admission): Temperature, bulging fontanelle, can suck or breastfeed, reduced mobility or floppy, respiratory rate, in drawing, grunting, central cyanosis Symptoms (history): Prolonged rupture of membranes (ROM) (>18 h), fever, difficulty breathing, severe vomiting, difficulty feeding or breastfeeding, convulsions, partial or focal fits, apnoea
Evidence of monitoring	Treatment sheet available and filled, vital signs chart available and filled, evidence of weight monitoring
Quality: interpersonal	
User-adherence adjusted coverage	
Outcomes-adjusted coverage	

Table S6 Exclusive breastfeeding

Study (data sources)	Nguhiu et al. 2017 (40) (DHS)
Intervention	**Exclusive Breastfeeding**
Target population	
Children	Children 0-5 mnths
Service contact	
Breastfed	Breastfed in last 24 hours
Input-adjusted coverage	
Intervention coverage	
Process quality-adjusted coverage	
User-adherence adjusted coverage	
Adherence to guidelines	Respondent reported exclusively breastfeeding in preceding 24 h AND no other complementary feed offered
Outcome-adjusted coverage	

Table S7 Postnatal care

Study (data sources)	Baker et al. 2015 (55) (HH survey; HF assessment; HCW interview)	Carvajal-Aguirre et al 2017 (31) (DHS)	Hategeka et al. 2020 (52) (DHS)	Marchant et al. 2015 (34) (HH survey; HF assessment; HCW interview)		Munos et al. 2018 (43) (MICS; HF assessment; HCW interview)		Okawa et al. 2019a (49) (HH survey)	Okawa et al. 2019b (46) (HH survey)	Shibanuma et al. 2018 (58) (HH survey)
Intervention	**PPC for mother in a health facility within 48hrs of delivery**	**Postnatal health check within 48 hours**	**Postpartum check-up before discharge**	**(1) PPC for mother within 48 hours of birth**	**(2) PNC for newborn within 48 hours**	**(1) postnatal care within 48 hours: structural quality**	**(2) postnatal care within 48 hours: process quality**	**PNC for mother & newborn**	**PNC for mother & newborn**	**PNC within 48 hrs & around 2 & 6 wks post-delivery**
Target population										
	Women with live birth in 12mnths prior to survey	Surviving children under 2 years of age at time of survey	Women aged 15-49 yrs with at least 1 live birth in 5 yrs preceding the survey	Women aged 13-49 who had a live birth in 12 mnths prior to survey	Women aged 13-49 who had a live birth in 12 mnths prior to survey	Women report a live birth in the 2 yrs preceding the survey	Women report a live birth in the 2 yrs preceding the survey	Women between 6 wks -12 mnths postpartum	Women aged 15-49 yrs delivered in 2 yrs prior to survey	Women aged 15-49 yrs delivered in 2 yrs prior to survey
Service contact coverage										
Facility based care	Women reported giving birth in a facility	Women reported skilled birth attendant at birth	Delivered in a health facility during most recent pregnancy leading to a live birth	Women reported at least 1 postpartum contact within 48 hours of birth	Women reported newborn had at least 1 postnatal check within 48 hours of birth	Sought facility based care within two days of birth	Sought facility based care within two days of birth	At least 3 contacts for PNC with healthcare providers, including first contact within 24 hours postpartum	Three contacts with healthcare providers within 48hours, at 1 week (3–10 days) and at 6 weeks (36–48 days) postpartum	Received PNC within 48 hours and around 2 and 6 weeks post-delivery
Input-adjusted coverage										
Inputs: service infrastructure										
Emergency transport						Emergency transportation				
Inputs: Staffing, training & guidelines										
Supervision						Supervised with observation				
Staff availability						24-hour staff coverage				
Trained: counselling PNC						Trained on counselling for PNC				
Trained: management of complications in pregnancy						Trained on management of complications of pregnancy				
Trained: PMTCT						Trained on PMTCT				
Trained: nutrition						Trained on nutrition counselling for newborn of mother with AIDS				
Trained: feeding						Trained on infant and young child feeding for HIV+ mothers				
Trained: PMTCT prophylaxis						Trained on PMTCT prophylactic treatment				
Inputs: Supplies & commodities										
Antibiotics						Injectable antibiotics				
Blood pressure apparatus						Digital BP machine or manual sphygmomanometer with stethoscope observed in service area				
Iron supplements/tablets	Facility with iron supplements available									

Scale						Infant weighing scale observed in service area				
Stethoscope						Stethoscope				
Thermometer						Thermometer				
Inputs: service availability										
ARVs						ARV to mother ARV to infant				
Counselling: Breastfeeding						Breastfeeding counselling				
Counselling: HIV prevention						HIV preventive counselling				
Counselling: HIV test						HIV test counselling				
Counselling: ITNs						Counselling on ITNs				
Counselling: newborn care						Newborn cares counselling				
HIV test						HIV test				
Inpatient						Inpatient				
Counselling: family planning						FP counselling				
Intervention coverage										
Anaemia								Women report anaemia checked	Haemoglobin assessment	
Baby weighed		Women reported newborn weighed at birth			Women reported weight checked					
Family planning							Family planning method			
Immunisation: BCG vaccination		Women reported BCG vaccination						Women reported BCG immunisation given	BCG immunisation	Received necessary immunisations
Immunisation: Hepatitis B								Women reported Hepatitis B immunisation given		
Immunisation: Oral polio vaccine		Women reported polio vaccination at birth							Oral polio vaccine	
Iron folate tablets							Iron tablets	Women reported iron folate tablets prescribed		
Vitamin A given to mother							Vitamin A capsules	Women report Vitamin A tablets prescribed	Vitamin A supplement	
Vitamin B given to mother								Women report Vitamin B tablets prescribed		
Process quality-adjusted coverage										
Quality: process										
Breastfeeding checked							Other assessments (breastfeeding, child's weight/growth, etc.)	Women report breastfeeding checked	Breastfeeding problem check Breastfeeding difficulties check	
Counselled on breastfeeding, thermal care and danger signs				Women reported being counselled on breastfeeding, thermal care and danger signs			Advice on preventive PNC (keeping baby warm, cord, breastfeeding, FP, postpartum hygiene, ITN)			Learnt about post-delivery complications among women and children
Counselled on danger signs, nutrition and family planning				Women reported being counselled on danger signs, nutrition, and family planning			Advice to seek care if child has any danger sign (fever, cold, difficulty to breastfeed,	Women reported family planning counselling		Learnt about nutrition, anaemia and breast feeding

							rapid/difficult breathing, etc.) Advice to seek care if mother has any danger sign (sudden and profuse bleeding, vomiting, faintness, fever, etc.)			
Maternal assessment							Initial assessment of mother's health (signs and symptoms since delivery)		Fundal height assessment Perineum/Lochia assessment	
Maternal blood pressure								Women reported blood pressure measured	Women reported blood pressure assessed	
Maternal temperature								Women reported temperature measured	Women reported temperature measured	
Newborn assessment					Women reported cord checked		Initial assessment of child's health (signs and symptoms since childbirth)		Umbilical cord/bleeding check	
Newborn examined					Women reported newborns body examined for danger signs		Physical examination of the child	Women report physical examination of newborn	General physical examination	
Newborn temperature measured								Women report newborn temperature measured	Newborn temperature measurement	
Postpartum check			Women report examined or asked questions about their health before discharge	Women reported breasts and bleeding checked			Physical examination of the mother	1. Women report breast and nipple checked 2. Women report vaginal healing checked 3. Women report uterus checked 4. Women report lochia checked 5. Women report emotional status checked	Bleeding check	
Timely postpartum check	Women report being checked within 48 hours of delivery	Women reported postnatal care for newborn AND mother within 2 d of birth	Women report examined or asked questions about their health within one hour of delivery							
Quality: interpersonal										
User-adherence adjusted coverage										
Adherence to guidelines		Women reported early initiation of breastfeeding AND no prelacteal feed during first three days of life								
Outcomes-adjusted coverage										

Table S8 Sick child care

Study (data sources)	Carter et al. 2018 (45) (HH survey; HF survey; HCW knowledge assessment)	Hategeka et al. 2020 (52) (DHS)			Koulidiati et al. 2018 (42) (HH Survey, HF assessment, Observation)	Leslie et al. 2017 (33) (DHS/MICS, SPA)	Leslie et al. 2019 (37) (ENSANUT [national survey]; HMIS)		Millar et al. 2014 (50) (HH survey)	Munos et al. 2018 (43) (MICS; HF assessment; Observations)		Nguhiu et al. 2017 (40) (DHS; SPA)	Nguyen et al. 2021 (44) (DHS, SPA)	Smith et al. 2010 (51) (HH survey)
Health service/intervention	**Treatment of diarrhoea, fever and/or ARI**	**(1) Treatment of pneumonia**	**(2) Treatment of diarrhoea**	**(3) Treatment of malaria**	**Treatment of illness**	**Treatment of diarrhoea, fever or ARI**	**(1) Treatment of diarrhoea**	**(2) Treatment of respiratory conditions**	**Care seeking and treatment for malaria**	**(1) sick child care (fever, cough or diarrhoea): structural quality**	**(2) sick child care (fever, cough or diarrhoea): process quality**	**Quality of primary care for children: treatment of ARI and/or fever**	**Sick child care (diarrhoea or ARI)**	**Treatment for malaria**
Target population														
	Mothers of children <5 years who reported at least one DHS illness (diarrhoea, fever, ARI or a combination)	Parental report children <5 who, in the past 2 weeks, have suffered from symptoms consistent with pneumonia (a cough accompanied by short, rapid breathing and difficulty breathing as a result of a problem in the chest)	Parental report children <5 who had diarrhoea in the past 2 weeks	Parental report children <5 who had fever in the past 2 weeks	Children under 5 years of age that experienced an illness episode during the 4 weeks prior to the survey date.	Children under 5 who had experienced diarrhoea, fever or acute respiratory illness in the prior 2 weeks	Parental report of child under 5 experiencing at least 3 days of diarrhoea or diarrhoea plus fever	Parental report of symptom of flu, cough, bronchitis, sore throat or pain in his/her ears past 2 weeks in child under 5	Mothers of children aged 0-59 mnths who reported a fever in the last 2 wks	Mothers of children under-5 yrs who reported child had fever, cough or diarrhoea in 2 wks before survey	Mothers of children under-5 yrs who reported child had fever, cough or diarrhoea in 2 wks before survey	All children under 5 yrs reported to have had acute respiratory illness and/or fever in the preceding 2 wks	All children alive between 0-59 mnths who had diarrhoea or ARI in the last 2 weeks	All children under 5 yrs with fever in the last two weeks
Service contact														
Seek care	Mother reported seeking care from any provider	Taken to medical facility for treatment (including public sector and medical private sector facilities, except for pharmacies and traditional practitioners)	Taken to medical facility for treatment (including public sector and medical private sector facilities, except for pharmacies and traditional practitioners)	Taken to medical facility for treatment (including public sector and medical private sector facilities, except for pharmacies and traditional practitioners)	Sought care at the nearest facility	An interaction with a health facility or formal provider	Visits to IMSS family medicine clinic due to diarrhoea	Visits to IMSS family medicine clinic due to non-chronic respiratory condition	Sought treatment at formal and informal treatment locations	Source of care where advice or treatment was sought.	Source of care where advice or treatment was sought.	Advice on treatment was sought from a medical provider	Sought care from a medical provider	Child taken for treatment or advice to community delivery point, public health facility or retail delivery point
Inputs														
Inputs: service infrastructure														
Ambulance/Emergency transport					Functional emergency vehicle available									
Patient waiting room					Patient waiting room available.									
Power/Electricity					Functional electricity source available									
Sanitation					Functional toilet facilities available									

Water supply					Functional water source and soap available in the consultation room									
Inputs: Staffing, training & guidelines														
Qualified HCW					Observed cases attended by a qualified HCW									
IMCI guidelines	Guidelines (IMCI guidelines or relevant guidelines or job aid available)									IMCI guidelines observed in service area			IMCI guideline: national guidelines for IMCI, IMCI chart booklet, IMCI card, other visual aids	
HCW Knowledge: breathing difficulties	Average performance on case scenarios				Vignette-based scenario: Breathing difficulties in a 1-year-old with simple pneumonia									
HCW knowledge: severe dehydration					Vignette-based scenario: Viral illness with severe dehydration in a 2-year-old									
HCW knowledge: lethargy					Vignette-based scenario: Lethargic 1-month-old									
Supervision	Supervision (received supervision visit with case management observation in past 3 months)									Supervised with observation				
Trained ARI										Trained on ARI diagnosis and management				
Trained diarrhoea management										Trained on diarrhoea management				
Trained iCCM										Trained on iCCM (CHWs)				
Trained IMCI	Training (at least one staff member with IMCI or relevant training)				Observed cases attended by a HCW trained in IMCI					At least one staff member providing the service trained in some aspect of IMCI in the last two years			Staff with any training on IMCI Guidelines	

Trained malaria diagnosis & management										Trained on malaria diagnosis and management				
Trained nutrition										Trained on nutritional assessment				
Trained paediatric HIV diagnosis & management										Trained on paediatric HIV diagnosis and management				
Inputs: Supplies & commodities														
ACT	Basic medicine: Artemisinin combination therapy (ACT)									Artemisinin combination therapy (ACT) any child dosage or formulation. Observed in service area OR where routinely stored; in stock with at least one valid.				
Anthelmintic													Albendazole/ mebendazole	
Antibiotic	Basic medicine: Oral antibiotic				Antibiotics in stock; ceftriaxone in stock					Cotrimoxazole or amoxicillin any child dosage or formulation. Observed in service area OR where routinely stored; in stock with at least one valid.				
Clock/timer										Timer				
Haemoglobin													Diagnostic capacity: Haemoglobin	
Injectable antibiotics	Severe/complicated illness medicines: Injectable antibiotics									Injectable antibiotics				
Injectable antimalarials	Severe/complicated illness medicines: Injectable quinine or artesunate									Injectable antimalarials				
Iron													Iron tablet	
IV fluids	Severe/complicated illness medicines: IV fluids				Dextrose solutions or dextrose containing intravenous fluids in stock									
Microscopy supplies	Diagnostics: General microscopy									Microscopy supplies				

	(functioning microscope and slides)													
ORS	Basic medicine: Oral rehydration solution				Isotonic fluid or Oral rehydration solution and nasogastric tube					Oral Rehydration Salts (ORS) sachets any child dosage or formulation. Observed in service area OR where routinely stored; in stock with at least one valid.			ORS	
Paracetamol					Paracetamol suppository in stock									
RDT	Diagnostics: Malaria Diagnostic (RDTs or microscopy)				Diagnostic: Malaria testing supplies in stock					Malaria rapid test or smear (microscope, slides, and stain). Able to conduct the test on-site (in the facility) and functioning equipment and reagents needed to conduct the test are observed on-site on the day of the survey. In area where tests for child health are carried out or anywhere in the facility where laboratory testing is routinely conducted				
Scale	Diagnostics: Malnutrition Diagnostic (MUAC or Scale + Height board + Growth chart)				Functional scale available					Child and infant scale. Weight gradations at minimum 250 grams and 100 grams. Observed availability, reported functionality, and in service area or adjacent area.		Observed availability of at least one working weighing scale	Scale (observed)	
Stethoscope	Diagnostics: ARI Diagnostic									Stethoscope. Observed availability,				

	(stethoscope or respiratory timer)									reported functionality, and in service area or adjacent area.				
Timer										Timer				
Thermometer					Functional thermometer available					Thermometer. Observed availability, reported functionality, and in service area or adjacent area.		Observed availability of thermometer		
Vitamin A													Vitamin A	
Zinc	Basic medicine: Zinc									Zinc sulphate tablets, dispersible tablets or syrup any child dosage or formulation. Observed in service area OR where routinely stored; in stock with at least one valid.			Zinc tablet/zinc sulphate syrup	
Inputs: service availability														
ARI	Diagnosis and treat ARI (by pathology)													
Care for children under-5										Facility offering preventive and curative care for children under 5				
Diarrhoea	Diagnosis and treat diarrhoea (by pathology)													
IMCI										Facility offering IMCI services				
Malaria	Diagnosis and treat malaria (by pathology)													
Malnutrition	Diagnosis and treat malnutrition (by pathology)									Facility offering malnutrition diagnosis and treatment				
Referral capacity	Facilitated referral capacity													
Intervention														
ACT														Child received an ACT

Antibiotics		Mother reported child received antibiotic pills, syrup or injections												
Antimalarial									Mother reported child took Artemisinin-based combination therapy (ACT) if the blood test is positive					Child received an anti-malarial
Deworming medication						Children 2-59mnths: deworming medication								
Malaria test				Mother reported blood taken from child's finger or heel for testing					Mother reported child received diagnostic blood test (either microscopy or RDT)					
ORT			Mother reported child received oral rehydration therapy (from oral rehydration salts (ORS), pre-packaged ORS liquid or other homemade fluids)											
Vitamin A dosage						All children: Vitamin A dosage								
Process quality-adjusted coverage														
Quality: process of care														
Check Convulsions						All children: history taking convulsions								
Check danger signs					Provider observed to ask for at least two general danger signs per IMCI guidelines						Observed checked for 3 danger signs			
Check diarrhoea					Provider observed to ask for presence of diarrhoea									
Check edema of feet						Children 2-59mnths: edema of feet								

Check Fever, cough/difficulty breathing, diarrhoea					Provider observed to ask for presence of fever Provider observed to ask for presence of cough	Children 2-59mnths: history taking cough or difficult breathing All children: history taking diarrhoea and blood in stool (dysentery) Children 2-59mnths: history taking fever					Observed checked for fever, cough/difficulty breathing, and diarrhoea			
Check health card											Observed checked health card			
Check immunisations					Provider observed to check child's current vaccination status	All children: checked immunisation card or immunised						Observed or HCW reported routine assessment of immunisation status		
Check mouth (thrush in IMCI)						Children <2mnths: mouth (thrush IMCI)								
Check pallor					Provider observed to check for signs of anaemia (conjunctivae, palms)	Children 2-59mnths: pallor					Observed checked for palmar or conjunctival pallor			
Check Vomiting						Children 2-59mnths: history taking vomiting								
Check: Ear problems					Provider observed to ask for presence of ear problems	Children 2-59mnths: history taking ear problems								
Check: Inability to drink						All children: history taking inability to drink anything								
Check: Maternal HIV status						All children: history taking Maternal HIV status								
Check: Normal feeding						Children <2mntths: history taking normal feeding pattern								
Check: Sick feeding						Children <2mntths: history taking sick feeding pattern								
Described danger signs requiring return to facility						All children: Described danger signs requiring								

						return to facility								
Directions for feeding						All children: Directions for feeding								
Explained how to administer prescribed medication						All children: Explained how to administer prescribed medication								
Gave diagnosis						Children 2-59mths: Gave diagnosis								
Plotted weight on chart						All children: plotted weight on chart								
Records												Observed or HCW reported keeping of individual patient records		
Scheduled/discussed return visit						All children: Scheduled/discussed return visit								
Take temperature					Provider observed to ask child's temperature	All children: temperature						Observed or HCW reported routine temperature taking and recording		
Timely treatment									Mother reported prompt care-seeking within the first 24 hours of symptom onset					Sought care within 48 hours
Treated according to guidelines											Observed child correctly treated per provider diagnosis	HCW reported providers follow IMCI guidelines to assess and treat sick children		
Weighed					Provider observed to checks child's weight	All children: weight					Observed weighed and weight plotted on growth chart	Observed or HCW reported child weight taken		
Quality: experience of care														
User adherence														
Outcomes-adjusted coverage														
							Visits to IMSS family medicine clinics that did not result in	Visits to IMSS family medicine clinics that did not result in						

							hospitalization due to diarrhoea for children under age 5	hospitalization due to non-chronic respiratory condition for children under age 5						

Table S9 Complementary feeding

Study (data sources)	Aaron et al. 2016 (63) (HH)	Leyvraz et al. 2016a (61) (HH)	Leyvraz et al. 2016b (62) (HH)	Leyvraz et al. 2018 (60) (HH)	Nguyen et al. 2016 (57) (HH)
Intervention	**Complementary feeding supplement**	**Fortified Complementary Food**	**Fortified Complementary Food**	**Home fortification with micronutrient powders**	**Fortification of complementary Foods with Micronutrient Powders**
Target population					
Children	Children aged 6-24 months (1) all children (2) children at-risk based on poverty, poor maternal dietary diversity and suboptimal feeding practices	Children aged 0-23 months (1) all children (2) children at-risk based on poverty and poor feeding practices	Children aged 0-35 months (1) all children (2) children at-risk based on poverty and poor feeding practices	Children aged 6-23 months (1) all children (2) children at-risk based on poverty and poor feeding practices	Children aged 6-59 mnths
Service contact					
Heard product	Caregiver ever heard of the product	Caregiver ever heard of Farinor or Nutribon	Caregiver has ever heard of Bal Amrutham	Caregiver has ever heard MNP	Caregiver has ever heard of or seen of the National Institute of Nutrition-specific micronutrient powder (Bibomix)
Received product			Caregiver ever received product		
Input-adjusted coverage					
Intervention coverage					
Consumed fortified food	Child ever been fed the product	Caregiver ever fed child fortified complementary food (Farinor or Nutribon)	Caregiver ever fed child fortified complementary food	Child ever given micronutrient powder	Child ever fed product
Process quality-adjusted coverage					
User-adherence adjusted coverage					
Partial		Child fed Farinor or Nutribon at least once in past mnth	Target child consumes Bal Amrutham sometimes or always	Child consumed at least 1 sachet of MNP in the past week	Consumed at least 1 sachet over the past week.
Effective	Child fed product at least one in the previous seven days	Child fed Farinor or Nutribon at least once in past 7 days	Child always consumes Bal Amrutham	Child consumed at least 3 sachets of MNP in past week	Consumed 3 or more sachets over the past week.
Outcome-adjusted coverage					

Table S10 Growth monitoring

Study (data sources)	Nguyen et al. 2021 (44) (DHS, SPA)
Intervention	**Growth monitoring**
Target population	
Children	All children alive between 0-59 mnths
Service contact	
Attend health service	All children who had diarrhoea or ARI symptoms for whom care was sought from a medical provider
Input-adjusted coverage	
Inputs: Staffing, training & guidelines	
Guidelines	Guidelines for growth monitoring (observed)
Training	Staff with any training on growth monitoring
Inputs: Supplies & commodities	
Growth chart	Growth chart (observed)
Length or height board	Length or height board (observed)
Scale	Child scale (observed)
Tape for measuring head	Tape for measuring head (observed)
Intervention coverage	
Process quality-adjusted coverage	
User-adherence adjusted coverage	
Outcome-adjusted coverage	

Table S11 Insecticide treated bed net (ITN)

Study (data sources)	Nguhiu et al. 2017 (40) (DHS)
Intervention	**Malaria prevention**
Target population	
	Children and pregnant women
Service contact	
	Live in household that own an ITN
Input-adjusted coverage	
Intervention coverage	
	Self-report slept under ITN the night before
Process quality-adjusted coverage	
User adherence-adjusted coverage	
Outcomes-adjusted coverage	

Table S12 Vaccination

Study (data sources)	Mmanga et al. 2021 (59) (DHS)	Mokdad et al. 2015 (35) (HH survey)				Nguhiu et al. 2017 (40) (DHS; SPA)	Sheff et al. 2020 (48) (HH survey)
Intervention	**Complete immunisation**	**(1) Timely MMR vaccine**	**(2) MMR vaccine: facility readiness (MMR in stock)**	**(3) MMR vaccine: facility readiness (MMR stock-out in last 3 mnths)**	**(4) MMR vaccine: facility readiness (ORS in stock)**	**Quality of primary care for children: complete set of basic vaccines**	**Complete set of basic vaccines: quality coverage**
Target population							
	Children aged 12–23 months	Children 13.5–59 months with a vaccination card	Children 13.5–59 months with a vaccination card	Children 13.5–59 months with a vaccination card	Children 13.5–59 months with a vaccination card	All children alive between 12-23 mnths	Children aged 12-23 mnths
Service contact							
Vaccination	Received either BCG or Penta1 vaccine during the past year	At least one caregiver-reported or card-documented MMR dose.	At least one caregiver-reported or card-documented MMR dose.	At least one caregiver-reported or card-documented MMR dose.	At least one caregiver-reported or card-documented MMR dose.	Received the complete set of vaccines as outlined in the Kenya Ministry of Health National Vaccination Schedule i.e. BCG, three doses of oral or intravenous Polio, three doses of Diphtheria, Pertussis, Tetanus, Hepatitis B and Haemophilus Influenza type B pentavalent vaccine, three doses of pneumococcal vaccine (from Jan 2011 onwards), and Measles vaccines	Received BCG vaccination
Inputs-adjusted coverage							
Inputs: Supplies & commodities							
MMR			MMR in stock on day of survey	MMR in stock on day of survey & stock out in three months prior to survey			
ORS					ORS in stock on day of health facility survey		
Scale						Observed at least one working infant weighing scale or child scale present	
Thermometer						Observed at least one thermometer	
Intervention coverage							
Additional vaccines	Received Penta 3 vaccine during past year						Received all three doses of the DPT vaccine
	Received with MR1 during the past year						
Process quality-adjusted coverage							
Quality: process of care							
Check immunisations						Observed or HCW reported routine assessment of immunisation status	
Records						Observed or HCW reported keeping of individual patient records	
Temperature						Observed or HCW reported child's temperature taken	
Weighed						Observed or HCW reported child weight taken	
Guidelines						HCW reported providers follow IMCI guidelines to assess and treat sick children	
Recommended according to schedule	Received BCG, OPV3, Penta3, PCV3, Rota2 and MCV1 vaccines	MMR vaccine given within recommended interval: administered between 11.5 and 13.5 months	MMR vaccine given within recommended interval: administered between 11.5 and 13.5 months	MMR vaccine given within recommended interval: administered between 11.5 and 13.5 months	MMR vaccine given within recommended interval: administered between 11.5 and 13.5 months		Received all of the basic vaccinations by 24 months: one dose of BCG at birth, three doses of the oral polio vaccine (excluding the dose given at birth), three doses of a DPT containing vaccine and hepatitis B vaccine at 6, 10,

							and 14 weeks, and one dose of the measles vaccine.
User-adherence adjusted coverage							
Outcomes-adjusted coverage							

Appendix 3 - Supplementary material: objective 3

Table S9 Components used to define each step of the coverage cascade for the two different data sources

Step of cascade	Measure	(1) NDHS and project data	(2) NDHS and routine data
Target population (population in need of the intervention)	Women who report a live birth	NDHS: live birth in the last 5 years	NDHS: live birth in the last 5 years
Service contact coverage (attends a health facility for birth)	Women report where they gave birth	NDHS: place of delivery • Home (respondent's or other) • Govt. health centre/post • Govt. hospital/private hospital or clinic	NDHS: place of delivery • Home (respondent's or other) • Govt. health centre/post • Govt. hospital/private hospital or clinic
Input adjusted coverage (health facility ready to deliver care): 1. Facility infrastructure	Communication	HF survey: Any means of communicating with another facility • Facility landline/mobile phone • Staff member mobile phone; • Phone outside the facility; OR • Radio.	
	Light source	HF survey: Functioning electricity supply on the day of the survey (either an electricity connection or an alternative power supply) OR a 24-hour functioning light source available in the labour ward.	
	Sanitation	HF survey: Toilets accessible to female facility users	
	Water supply	HF survey: Source of clean running water (e.g. bucket and plug or piped water)	
2. Staffing & training	Skilled birth attendance	HF survey: Last seven days facility had at least one midwife/clinician available 24 hours a day, 7 days a week	DHIS2: All deliveries attended by a skilled birth attendant
3. Drugs & commodities	Anticonvulsants	HF survey: Magnesium sulphate available in the facility on the day of the survey	DHIS2: no stock out of magnesium sulphate in the past one month

Step of cascade	Measure	(1) NDHS and project data	(2) NDHS and routine data
	Blood pressure machine	HF survey: Blood pressure machine (sphygmomanometer) available in the service area.	
	Delivery pack	HF survey: Clamp or umbilical tie, sterile scissors or blade; AND suture material with needles available in the service area.	
	Newborn resuscitation device	HF survey: Functioning bag & mask size 0 (for preterms) AND size 1 (for term babies) available in the service area	DHIS2: no stock out of resuscitation equipment in the past one month
	Gloves	HF survey: Disposable gloves available in the service area.	
	Infection control	HF survey: soap and water for the purposes of hand washing OR alcohol based hand rub inside the labour room.	
	Intravenous fluids and infusion set	HF survey: Intravenous fluids with infusion set available in the service area	
	Scale	HF survey: Accessible and working baby scale available in the service area.	
	Suction apparatus	HF survey: Newborn suction device OR mucus trap/suction machine available in the service area	
	Uterotonic	HF survey: oxytocin, misoprostol OR ergometrine available in the facility on the day of the survey	DHIS2: no stock out of uterotonic (either oxytocin or misoprostol) in the past one month
Intervention coverage (receives services and medication)	Administers uterotonic	CO: Birth attendant observed to administer uterotonic	NDHS: Woman reports received injection immediately after delivery ***DHIS2: Active Management of 3rd stage of labour***
	Baby weighed	CO: Baby's weight observed to be recorded	NDHS: Weighed at birth based on health card or mother's recall ***DHIS2: Birth weight recorded for all live births***
	Thermal care	CO: Birth attendant observed to dry baby immediately with towel, place the newborn on mother's abdomen or if not placed skin-to-skin to wrap baby in dry towel AND baby not bathed within the first hour after birth	NDHS: Women reports child put on mother's chest and bare skin after birth AND baby not bathed within the first hour of birth. **NDHS: baby *wiped dry in as few minutes after birth*** ***DHIS2: Babies put to breast within 1hr with skin-to-skin to keep warm***
	Monitoring progress	CO: Birth attendant observed to take maternal blood pressure	

Step of cascade	Measure	(1) NDHS and project data	(2) NDHS and routine data
Quality-adjusted coverage (receives timely, appropriate, responsive and respectful care)	Explain what will happen in labour	CO: Birth attendant observed to explain procedures to woman (support person) before proceeding	
	Support person present	CO: A support person (companion) for mother is observed to be present at birth	
	Patient satisfaction with care received	CO: Woman would recommend someone else to deliver in the health facility	

TABLE NOTE: HF=health facility assessment, CO=clinical observations. Items highlighted in **bold and italicised** were not available: DHIS2 these indicators are captured at facility level but not included in monthly monitoring reports and NDHS data on immediate drying has not been made available in the publically available recode dataset.