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Which demand and supply-side characteristics are associated with coverage of childhood vaccination, antenatal care, and facility births? A multilevel study on the uptake of Maternal and Child Services in Guinea-Bissau

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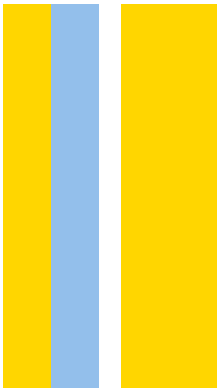

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Resumo

Introdução: A mortalidade materna e de menores de cincos anos permanece alta na Guiné-Bissau. Serviços de Saúde Materno-Infantil (SMI), nomeadamente consultas pré-natais, partos institucionais e vacinação infantil, podem contribuir para combater este problema de saúde pública. Contudo, a sua cobertura continua baixa. Este estudo pretende estimar que características dos centros de saúde, geográficas e materno-infantis podem influenciar o uso de SMI nas regiões guineenses de Bafatá, Biombo e Oio. **Métodos:** Colheram-se características de 35 centros de saúde e usaram-se dados secundários do Sistema de Vigilância Demográfica em Saúde do Projeto de Saúde Bandim. Incluímos 1,739 crianças para estudar cobertura vacinal, 3,419 crianças para estudar os cuidados pré-natais e 3,682 crianças para partos institucionais. Foram utilizados modelos mistos de regressão logística de quatro níveis, compostos por características fixas materno-infantis (nível inferior), de centro de saúde e geográficas (nível superior), tendo o Grupo familiar, Aldeia e Área Sanitária como interceptos aleatórios. **Resultados**: Distância e qualidade da infraestrutura do centro de saúde, custo do cartão de saúde reprodutiva, disponibilidade de veículos de evacuação, ordem de nascimento, estação do ano, idade materna, etnia, educação, nível socioeconómico e parto institucional prévio foram associadas a quatro ou mais consultas de cuidados pré-natais e ao parto institucional. Nenhum fator preditivo foi associado à vacinação completa infantil. Variáveis de nível superior explicam mais efeitos de cluster do que variáveis de nível inferior. **Conclusão:** Para combater elevadas taxas de mortalidade materna e de menores de cinco anos, é necessário assegurar a qualidade e cobertura dos SMI. Esta última pode ser aumentada através da melhoria de infraestruturas e acessibilidade aos centros de saúde, disponibilidade de veículos de evacuação, eliminação de custos associados às consultas e do reforço da educação materna e nível socioeconómico.

Abstract

Background: Maternal and under-five mortality rates remain high in Guinea-Bissau. Maternal and Child Health Services (MCHS), namely Antenatal Care, facility births, and childhood vaccination may contribute to tackle these public health issues. Yet, its coverage remains suboptimal. This study aimed to assess which health center, village geographical, and child-maternal characteristics can influence the uptake of MCHS in the Bissau-Guinean regions of Bafatá, Biombo and Oio. **Methods**: We collected characteristics of 35 health centers and used secondary data from the Bandim Health Project's Health and Demographic Surveillance System. We included 1,739 children to study vaccination coverage, 3,419 children for Antenatal Care, and 3,682 children for facility birth. Four-level mixed effect logistic regressions, composed of child-maternal (lower-level), health center and village geographical (upper-level) fixed characteristics accounted for Family group, Village, and Sanitary Area as random intercepts, were employed. **Results**: Distance and quality of health centers' infrastructure, cost of the reproductive health card, evacuation vehicles, birth order, season of the year, maternal socioeconomic level, education, age, ethnicity, and history of facility delivery were associated with four or more Antenatal Care visits and facility birth. No predictor was associated with full childhood vaccination. Upper-level variables accounted for more clustering effect than lower-level variables. **Conclusion**: To tackle high maternal and under-five mortality rates, the quality and coverage of MCHS must be ensured. The latter can be increased by improving infrastructure and accessibility to health centers, evacuation vehicles' availability, eliminating the cost of the reproductive health card, and reinforcing maternal education and socioeconomic level.

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List of acronyms

AIC-Akaike's Information Criterion

ANC-Antenatal Care

aOR-Adjusted Odds Ratio

AM-Ante Meridiem

AUC-Area Under the Receiver Operating Characteristic (ROC) Curve

BIC-Bayesian's Information Criterion

BCG-Bacillus Calmette-Guerin

BHP-Bandim Health Project

CI-Confidence Interval

COVID-19-Coronavirus disease

CHW-Community Health Worker

HDI-Human Development Index

HIV-Human Immunodeficiency Virus

HDSS-Health and Demographic Surveillance System

ICC-Intracorrelation Cluster

IPV-Injectable Polio Vaccine

IQR-Interquartile Range

LMIC-Low-Middle Income Country

MCHS-Maternal and Child Health Services

MOR-Median Odds Ratio

MMR-Maternal Mortality Ratio

MV- Measles Vaccines

NGO-Non-Governmental Organization

OPV-Oral Polio Vaccine

OR-Odds Ratio

PIMI-Programa Integrado para a Redução da Mortalidade Maternal e Infantil (Programme for reduction of maternal and child mortality)

PCV-Pneumococcal Conjugate Vaccine

PCV-Proportional Change in Variance

PM-Post Meridiem

SDG-Sustainable Development Goals

STATA-Statistical Software for Data Science

TBA-Traditional Birth Attendant

UNICEF-United Nations International Children's Fund

uOR-Unadjusted Odds Ratio

U5MR- Under-five Mortality Rate

VIF-Variance Inflation Factor

XOF-West African CFA franc

WHO-World Health Organization

YF- Yellow fever

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Km-kilometers

1.Background

1.1 Political and social context of Guinea-Bissau

Guinea-Bissau is a relatively small country located in West Africa, with approximately 36,125 km^2 of surface area (1). The nation has an estimated population of 2,016 million people (1) bordering countries such as Senegal, in the North, and Guinea, in the East. The southern and western borders are delimited by the Atlantic Ocean, where the Bijagós' Archipelago, the insular part of to the country, lies. The Autonomous Sector of Bissau, the political, economic and administrative capital (2), is where roughly 20% of the population resides. There are eight more administrative regions (mostly rural) where the rest of the population is distributed: Bafatá, Biombo, Bolama/Bijagós, Cacheu, Oio, Quinara, and Tombali (3) (Fig. 1).

As a former colony tied to Portugal, its independence was declared in 1973. Yet, this nation's history has been troubled with political and social disruptions, with only one president so far being able to complete his mandate (3). Several coup attempts motivated by military upheavals culminated in a civil war between 1998 and 1999 that devasted national public services (3). From 1999 to 2009 there was a government turnover every year with one President being assassinated in 2009. Until 2011 there was a period of stability, being again disrupted by a military coup in 2012 that has negatively impacted the country until today (4). The last coup attempt, in February of 2022, led to the dissolution of the parliament and new elections in June 2023.

In a population of about 2 million inhabitants, 27 to 40 different ethnicities coexist in the country (3). Accurate and credible socio-demographic composition is hard to find, but in a 2015 governmental database, the Balanta and the Fula ethnicities were the majority with 30% of the population belonging to these ethnicities (each), succeeded by Manjaco (14%), Mandinga (13%), Pepel (7%), and other unspecified smaller ethnicities (6%) (3). Guinea-Bissau is, in fact, the 15^{th} most ethnically diverse country in the world (5). Each ethnicity has

its own culture, language, and tradition, and tends to concentrate in certain geographical areas.

For instance, the Bijagós' ethnicity is matrilineal, and its mostly distributed across the 100 islands of the Bijagós' Archipelago, living of piscatory trading. The other ethnicities are patriarchal. Balantas are dominant in the armed forces and mostly reside in the southern coastal area; Mancanha and Manjaco are mostly farmers and live in the central and northern coastal regions; and the ethnic group Pepel, concentrated in the western part, are cashew producers (6, 7).

Fig. 1. *Political map of Guinea-Bissau (8)*

Contributing to this heterogeneity is the diversity of languages spoken in the country. The official language is Portuguese, but it is mostly pushed to the second or even third place of the most spoken languages. The great majority of Bissau-Guineans speak Creole, the *lingua franca*, followed by the specific languages from each ethnic group (3).

In terms of practiced religion, in 2020, most of Bissau-Guineans were Muslim (46%), while a considerable proportion practiced folk/animist religion (31%) and 19% followed Christianity. The remaining 4% followed other religions or were unaffiliated (3). The ethnic groups Fula and Mandinga compose the Muslim majority, although still holding traditional religion beliefs. The Christian population is represented primarily by Pepel, Manjaco, Balanta, and Mancanha (9).

1.1.1 Human and infrastructure development and adjacent gender disparities in Guinea-Bissau

This politically unstable context contributes to the stagnation of economic and infrastructure development. Indeed, the electricity sector, for instance, is only accessed by an estimated 20% of the population and is mainly consumed in the capital (10). Transportation is limited by the fact that only 453 kilometers (km) out of 4,400km of existing roadways are paved, and no railroads are available. The ports are degraded and maritime connections between the islands and continental Guinea-Bissau are limited and unreliable (1). During the rainy seasons (from June to November) roads often become impassable. Lack of suitable sanitary facilities and potable water are still challenges faced by many. For instance, in 2020, only 24% of the urban dwellers used safely managed drinking water services, this number declining to 11% in rural areas (11). In the same year, merely 22% of urban residents had access to safely managed sanitation services, decreasing to 4% in rural areas (12).

Not only infrastructure development is markedly hampered. Guinea-Bissau was ranked, in 2021, as the 15th least developed country in the world out of 188 countries, with a Human Development Index (HDI) of 0.483 (13). For comparison, in the same year, Portugal was ranked in 38th place with a HDI of 0.866 and Denmark in 6th place with a HDI of 0.948 (13).

Accounting to, and a result of the low HDI, is the low male life expectancy at birth, that reaches only 62 years, whereas women life expectancy reaches 66 years (3). In fact, only 3% of the population reached 65 years or above in 2021 estimations, with the rest of the Bissau-Guinean population being very young. That is, aligned with what is observed in other Low-Middle Income Countries (LMIC) and sustained by the high fertility ratios, in 2021, 42% of

the total population was represented by people aged 0-14 years and people aged 15-64 characterized 55% of the citizens (14).

Gender inequities are also observed. The World Bank classifies Guinea-Bissau as a country with a low rating of gender equality, where policies and laws that promote equal access between genders in various domains are not enforced (15). Traditional gender roles remain in place and women suffer the double burden of being mothers and primary caretakers but also income earners for the household (4). As of 2020, 8% of women aged 20-24 years were married before age 15, and 26% before age 18. To note that, already in 2011, a national law on reproductive health and planned parenthood raised the minimum age of marriage to 18 years (16). Polygamous weddings are not uncommon, and one in every three women aged 15-49 years is involved in a polygamous union (17). A half (52%) of women aged 15-49 years have undergone female genital mutilation (18), seemingly most predominant in the farthest regions of Bafatá and Gabu (19). The prohibition of this practice is also contemplated in the former law, yet law enforcement seems to be ineffective.

Women literacy rates are lower than men's literacy rates (33% versus 52%, respectively) (17), probably hindering their health. Exposure to media is also more prevalent in the male gender: 20% of men aged 15-49 years are exposed to three types of media (journal, radio, and television) weekly, while only 5% of women of the same age group are exposed (17). In 2021, solely 11% of Bissau-Guinean women were employed, salaried workers, contrasting with 24% of Bissau-Guinean employed, salaried men (20).

1.2 Guinea-Bissau's national healthcare system

1.2.1 National healthcare system's organization and infrastructures

The nation's dependence on foreign economic aid for health, education and economy is almost total (90%) and the high political instability translates in a continuous rotation of leaderships in the health sector (2). In reality, government expenses with health mostly just cover employees' salaries, but delays in payment are frequent, and strikes in the sector recurrent (2).

In that sense, it cannot be said that Guinea-Bissau possesses an established national healthcare system (1, 21). Nevertheless, in terms of health administration, the administrative regions are further subdivided into 11 Sanitary Regions and hierarchized in local, regional or central levels, which theoretically correspond to primary, secondary and tertiary levels of care (22). The local level has 114 Sanitary Areas and incorporates the health centers defined according to geographical criteria (2). The regional level involves the Direção Regional de Saúde (Regional Health Directorate), other administrative structures, regional hospitals, and drug warehouses. The central level, that includes the Hospital Nacional de Simão Mendes (National Hospital of Simão Mendes), the reference hospital, and other disease-specialized hospitals, sets health policies and regulations (23) .

The Central de Compra dos Medicamentos Essenciais (Office for the Central Purchase of Essential Medicaments) is a part of the national public health system, and the main institution responsible for the purchase, storage and distribution of medicine and other supplies to health facilities in the country (not free-of-charge) (24). Medicine supply is very precarious, health regions are not periodically provided with essential drugs and quality control is even more deficient (24). Drugs or consumables out-of-stock are a recurrent issue (24) and difficulties with the maintenance of cold-chains are also recounted (2).

The country has, in total, six types of health facilities: type A, B and C health centers, maternal and child health centers, regional hospitals and one reference hospital, but health infrastructures distribution is highly uneven (25). A by-product of the social and geographical circumstances (e.g., low density of physician per inhabitants, population very dispersed and residing far from health facilities) is the great diversification and specialization of the peripheral health centers, so that distinguishing health facilities based on the level of care that they provide may reveal itself as difficult (26). The reference and regional hospitals provide secondary and tertiary care, but often also primary care (26). On the same level, primary care health centers end up providing secondary and tertiary care, performing small surgeries, blood transfusions or hospitalizations (26). On that note, the classification of the primary health centers (i.e. A, B, and C) is dependent on their ability of delivering complex health interventions: type A health centers are characterized by having a medical center with surgical center, type B are distinguished by having a medical center and type C provide the most basic care and are run by nurses and midwifes (27). Countrywide, there are only eight type B health centers and seven type A (27). The rest, 108 health centers, are type C, the most common type of health facility found. Eighty two percent of rural areas only have health centers type C, being the only formal care that this population can receive locally (28). Field observations attest to the existence in some Sanitary Areas of satellite health centers, smaller health facilities run by the main health center's health workers, that although working inconsistently and unpredictably, may serve as a backup for the main health center.

Despite the different health infrastructures available in Guinea-Bissau, the focus of this study are health centers' characteristics exclusively, and not characteristics of health facilities in general. The base of the Bissau-Guinean's health system are primary health centers, as they not only exist in greater quantity than other type of health facilities and serve a higher percentage of the population (27), but they are the ones that (mostly) provide maternal and child promotive, preventive and curative care. Still, for the purpose of coherence, further in the text, the term "health facility" will be used as an umbrella term for health centers, hospitals, and other type of health establishments, whereas "health center" will be employed to describe primary care facilities.

1.2.2 Human resources

As for human resources, a 2019 World Bank report described the existence of only 388 physicians, 1600 nurses (the group most represented, with 46%), 158 midwives, 522 mid-level technicians, 115 other top-level professionals, and 555 other health professionals in a total of 3,448 publicly employed health professionals in the country (28). There is an ever-present lack of capacity for widespread, permanent, and high-quality data collection, with over-dependence on foreign assistance due to a dearth of local key health participants such as epidemiologists, demographers, and responsibles for data collection at health facilities. *"Brain drain"* of the Bissau-Guinean health force is a phenomenon occurring in the country that further depletes human resources (1).

Thus, the traditional sector seems to be the first line of medical care, even in these days, with traditional healers or *djambacós/muro* remaining, as a result, very much sought (1). In an effort to narrow the gap between health services and the communities that they serve, and therefore decreasing dependency on traditional healers, a system based on Community Health Workers (CHW) was implemented in 2012 (29). As what can be observed in many other African countries, these workers are an essential link between these two services, especially in regions where healthcare is essentially unavailable or hard to reach (30). These agents are chosen by the communities themselves and although having little formal health training, WHO (World Health Organization) Africa highlights their efficiency, during the Millenium Development Goals period, in reducing child mortality and improving maternal health (30).

1.2.3 Barriers to care

Informal payments are generalized in the country, aggravating the already existing inequities. Patients may have to pay not only consultation fees at the health centers but also medicines and other type of health services as well (e.g. ambulances) (31). Prices can be, however, extremely high and out-of-pocket expenditure in health has been massively increasing, with data from 2019 mentioning an out-of-pocket expenditure of 65% (32). A great percentage of this out-of-pocket payments are reported to be used in order to maintain health facilities and

to pay for supplies (1). We notice that children under 5 years and mothers are exempt from paying fees, so delivery assistance, reproductive health consultations, vaccination or evacuation, for example, should be free to this population (33).

Access to health facilities is not only problematic because of transport and services affordability but the geographical distance also comes in play. Over 40% of the population lives 5km away from the nearest primary health care facility, and transportation importantly depends on both meteorological and road conditions (26).

Alongside with affordability and physical accessibility to the national health care system, other challenges arise from the social heterogeneity of the Bissau-Guinean population. For example, obstacles to family planning information and services to the Islamic community have been described, derived from cultural and language barriers (1). These language barriers also extend to the rest of the ethnic groups and are coupled with the already mentioned extremely low literacy rates (1). It is noteworthy to know that the distribution of health professionals throughout the country's health centers occurs without taking into account if these professionals speak the ethnic language of the predominant community (34).

Cultural or religious traditions are deeply rooted and may act as either facilitators or barriers to Maternal and Child Health Services (MCHS) seeking. For instance, Bissau-Guineans that follow animism, have beliefs and behaviors that remain until today (4). Some of these also turn out to be justifications for an inferior status of the female gender or for other harmful practices, like female genital mutilation being warranted as a requirement for Islam (4). For a woman, bearing children is seen as crucial for strengthening their lineage and as social security, being also a source of competition with the husband's other co-wives (34). This means that pregnancies in the first trimester might be hidden to prevent others from conjuring curses, leading many women to only seek MCHS later in the pregnancy (34). A woman may be also more valued if she is able to deliver at home (34). Other issues may arise given the fact that parenthood and birth are considered a female concern, not to be exposed to male health professionals (34).

The national plan for the development of human resources in health (35) summarizes the perils affecting the progress of Guinea-Bissau, namely: (i) the social challenges, such as the rapid population growth and urbanization rate, low literacy, low Portuguese-language

expertise between health professionals, fragile public institutions and civil society, corruption; (ii) the economic challenges, such as the chaotic and predominantly informal economy and high dependency of external donors; (iii) globalization, which leads to several challenges like "*brain-drain"* and demands from international organizations; (iv) coverage challenges; (v) professional challenges, such as outdated health policies, neglected professional values, lack of professional regulatory organisms in health, lack of biological and physical safety for health professionals; and (vi) issues at the level of the administration of human resources. The Ministry of Public Health is criticized by its limited capacity of strategic planning, budget management, and implementation of health policies on medium and long term (23).

1.3. Maternal and child mortality in Guinea-Bissau

1.3.1 Definitions and trends

To improve peace and prosperity for all citizens, presently and into the future, all United Nations members agreed on 17 Sustainable Development Goals (SDG). The SDG number three "Ensure healthy lives and promote well-being for all at all ages" integrates two targets intended to "By 2030, reduce maternal mortality ratio to less than 70 per 100,000 live births" and "By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce […] under-5 mortality to at least as low as 25 per 1,000 live births" (36).

This subject presents itself as particularly important to address in Guinea-Bissau. As of 2020, the Maternal Mortality Ratio (MMR), the number of maternal deaths that occur in a population per 100,000 live births, is estimated to be as high as 725 deaths/100,000 live births. Admittedly, a clear progression is visible: in 2000, MMR was calculated at 1,300 deaths/100,000 live births. However, this indicator in Guinea-Bissau is performing far worse than in sub-Saharan Africa, where the MMR is calculated at 536 deaths/100,000 live-births (37). In 2021, the Under-five Mortality Rate (U5MR), defined as the number of children who die before achieving the age of 5 years old/1,000 live-births, was estimated at 74 deaths/1,000 live-births which, while being similar to sub-Saharan Africa estimates (73 deaths/1,000 live-births), is still exceedingly high. Again, it is to denote the remarkable progress: in 2000, the U5MR was at 175 deaths/1,000 live-births (38).

1.3.2 Underlying causes

A study that analyzed maternal mortality in Hospital Nacional de Simão Mendes during 2013 and 2018, reported that the leading cause of maternal death was hemorrhage (50%), followed by hypertension (17%), abortion (4%), cardiopathy (1%), malaria (2%), infection (2%), delivery (8%), among other causes (14%) (39). Most maternal deaths are preventable, as solutions to prevent them or manage its causes exist. The socioeconomic background of the

mother and the family that she belongs to, and her obstetric conditions (e.g., high parity, maternal age of less than 19 or more than 35 years, unsafe abortion practices) are other factors implicated in maternal mortality (40, 41). In fact, these obstetric factors can contribute to an increase of the lifetime risk of maternal death, as women who bear children early in life tend to have more children in general (40).

In Guinea-Bissau, as of 2021, the total fertility rate was of 4 births/per woman (42). Although steadily decreasing and performing slightly better than other sub-Saharan countries (where the total fertility rate is of 4.6 births/per woman), it is still relatively high. In 2021, the adolescent fertility rate was of 88 births per 1,000 women aged 15-19 years (43) but a remarkable declining tendency should be mentioned. Concerning age-specific fertility rates, particularly in women aged 35 years and above, between women aged 40-44 years, in 2020, there were 71.2 births/1,000 women and, among women aged 45-49 years 20.2 births/1,000 women, contributing to this overall risk of death due to pregnancy (44). Aggravating this issue, is the fact that, in 2019, only 21% of married women aged 15-49 referred to use any sort of contraceptive method, lower than their pairs in the sub-Saharan region, where 33% of women recurred to contraceptive methods (45).

On the other hand, leading causes of U5MR in Guinea-Bissau incorporate, among others, lower respiratory infections (16%), diarrhoea (15%), malaria (13%), Human Immunodeficiency Virus (HIV)/ Acquired Immunodeficiency Syndrome (7%), tuberculosis (5%) or measles (4%) (46). Like some maternal causes of death, infant mortality can, to some extent, be prevented through mother and child's access to hygienic delivery facilities, medicine and vaccines (47).

1.3.3 Maternal and child health services as promotive, preventive, and curative care in Guinea-Bissau

Key elements to undertake the high MMR and U5MR, especially in sub-Saharan countries, include parenthood planning, skilled birth attendance during pregnancy, delivery and post-partum (48), and effective emergency obstetric care and referrals system (1). Indicators such as the proportion of pregnant women receiving at least four Antenatal Care (ANC) visits,

delivering at a health facility, and the proportion of 0-11 months children fully vaccinated, can be used to assess the uptake of MCHS and, therefore, coverage of these services (23).

Once a woman is pregnant, ANC presents as an important strategy to reduce mortality, both maternal and child, as women can be preventively prepared for delivery and warning signs, as well as receive important micronutrient supplementation, vaccination against tetanus, malaria prophylaxis, among others (49). Women at risk of developing complications during labor or delivery can also be identified (50).

ANC visits are also an opportunity for health professionals to motivate women to choose to deliver at a health facility. In settings where home births are prevalent, women and their families need to be conscious that complications during childbirth and post-partum can be more quickly addressed if the birth is occurring at a health facility (51), and both neonatal (52) and maternal deaths (53) can be prevented. WHO models that included four ANC visits were the standard indicator for the SDG, since attending at least four ANC visits increased the probability of receiving effective maternal health interventions during the prenatal period (54). Recent WHO guidelines indicate that a minimum of eight ANC visits during pregnancy are now recommended to reduce perinatal mortality and to improve women's experience of care (55). However, as a substandard coverage of ANC in the studied regions is expected, the threshold of four ANC visits was adopted for this research.

ANC and delivering at a health facility are not only targeted at reducing MMR but also U5MR, as the latter is inevitably linked to maternal health (56). Child vaccination is a complementary strategy to reduce deaths, particularly in children under 5 years. Child vaccination not only prevents the spread of infectious diseases, leading causes of child mortality in Guinea-Bissau, but can also contribute to the reduction of child mortality through its non-specific effects on not-targeted infections (57).

The Bissau-Guinean's routine vaccination calendar includes 16 vaccines before 12 months of age: at birth the Bacillus Calmette–Guérin (BCG) and the first dose of oral poliovirus vaccine (OPV0); at 6 weeks the first dose of the Pentavalent vaccine (Diphtheria, Pertussis, Tetanus, Hepatitis B, and Haemophilius Influenzae type B, so Penta 1), along with a second

dose of OPV (OPV1), first dose of Pneumococcal Conjugate Vaccine 13 (PCV13-1) and the first dose of Rotavirus (Rota 1); at 10 weeks the second dose of Penta (Penta 2), PCV13 (PCV13-2) and Rotavirus (Rota 2) and finally the third of OPV (OPV2); at 14 weeks the fourth dose of OPV (OPV3) is combined with the first dose of Injectable Polio Vaccine (IPV1) to boost immunity, adding the third dose of Penta (Penta3) and PCV13 (PCV13-3); at last, at 9 months of age children should receive the measles vaccine (MV) and against yellow fever (YF) (58) (Fig. 2).

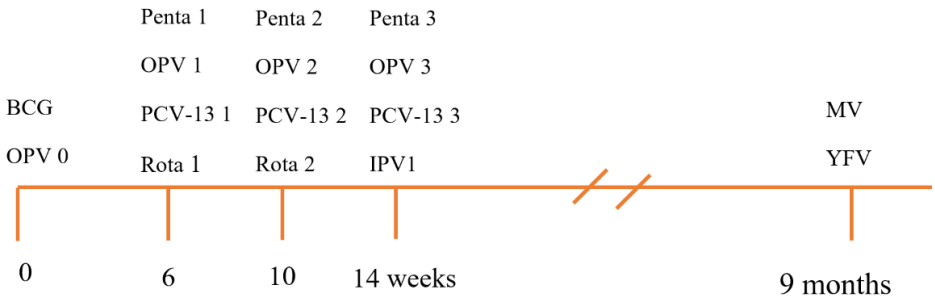

Fig. 2. *Bissau-Guinean's routine vaccination calendar*

It is necessary to emphasize the evidence that demonstrates that coverage of MCHS in Guinea-Bissau, namely of ANC visits, childhood vaccination and facility delivery, does not necessarily equate with reduction of U5MR (59) or MMR (1). Such a pattern was also observed in Ghana (60). In fact, Fisker et al. (61) underline that neonatal, infant, and U5MR, in Guinea-Bissau, does not show a decreasing tendency since 2019 anymore, but rather reached a plateau. This implicates the existence of other components that impact both coverage of MCHS and/or maternal and child mortality (1, 59). Reducing maternal and child mortality effectively assumes that *coverage of maternal and child services* is linked to *quality of the maternal and child health services,* with these two dimensions sharing a bidirectional, interdependent relationship (Fig. 3). *Quality of the maternal and child services* appears to be inseparable from *coverage of maternal and child services*, since the woman's perceived quality of care can be associated with her uptake of MCHS and uptake of MCHS, consecutively, associated with quality of service. In other words, a woman's negative or positive experience of care may be a determinant of her uptake of MCHS (62, 63) and higher uptake of MCHS (related to higher coverage) associated with understaffing or overburdening

of health workers (64) or shortage of equipment/medicines (65) may reduce the quality of care at the health facility. Furthermore, it can also be expected that altering quality or coverage without changes to the other component can alter mortality.

In light of that, though these dimensions share a common ground, measurement of coverage of MCHS's indicators - and the factors that lead to their uptake - and quality of MCHS require different instruments and approaches. For instance, quality of the service, can be partitioned into "quality of the provision of care within the institution" (66, 67), the care provided by health centers and the health professionals, and "quality of care experienced by users" (66, 67), the care experienced by women and their children, with both components contemplated in order to measure the quality of a health service (66).

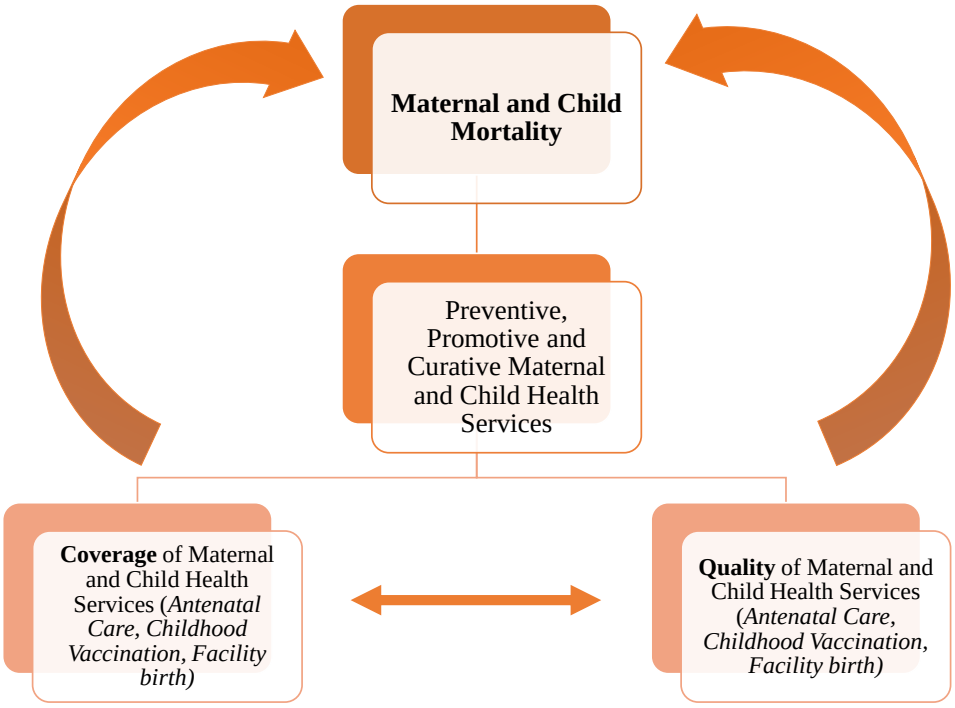

Fig. 3. *Relationship between maternal and child mortality, and coverage and quality of Maternal and Child Health Services*

1.3.3.1 Programa Integrado para a redução de Mortalidade materna e Infantil (PIMI)/ Integrated Programme for the Reduction of Maternal and Child Mortality

The Programa Integrado para a redução de Mortalidade materna e Infantil (PIMI) (Integrated Programme for the Reduction of Maternal and Child Mortality) was a Program framed in the

2008-2017 Plano Nacional de Desenvolvimento Sanitário II (National Sanitary Development Plan) and it is now framed in the current Plano Nacional de Desenvolvimento Sanitário III (2018-2022) and in the *Plan Operational de Passage a l'Echelle Nationale des interventions a haut impact - Strategies pour l'acceleration de la reduction des mortalités maternelles, neonatales et infanto-junenile en Guiné-Bissau*, identifying reducing maternal and child mortality as a priority for the country (68).

Its core sponsor is the European Union and its locally implemented by Non-Governmental Organizations (NGO) such as Instituto Marquês de Valle Flôr, the United Nations International Children's Fund (UNICEF) and the Entraide Médicale Internacional. The first phase of the Program, PIMI-I, took place between July 2013 and November 2016 in the Sanitary Regions of Cacheu, Biombo, Oio and Farim. The second phase started in June 2017 and ended in November 2021, this time being phased out to all the Sanitary Regions in the country. The present study is integrated in the third phase of PIMI labelled PIMI-III, introduced in June 2022 (33).

PIMI's purpose is, as the name indicates, to "[…] contribute to reducing maternal, neonatal and child and juvenile mortality in Guinea-Bissau, and to ensure better access to quality health care for pregnant and postpartum women and children under 5" (33), hopefully timely reaching the goals delineated by the SDG. Better access to quality care should be achieved by ensuring that consumables and medicine are permanently available at health facilities, free of charge, by developing effective referral systems, increasing theoretical and practice training of health professionals in key areas of maternal and child health (as well as providing monetary incentives), by providing water supply systems and electric power to health facilities and rehabilitating infrastructures, among others (33). It was in these circumstances that MCHS fees became entirely supported by the European Union financing through PIMI-II. In fact, PIMI, through its local partners, was the largest supplier of medicines (74%), supplies (60%), and equipment (53%) (33).

The data collected through the Health and Demographic Surveillance System (HDSS) of the Bandim Health Project (BHP) before, during and after PIMI, allowed for an evaluation of the

Program's implementation (to mention that PIMI's indicators were focused on the indicators uptake of facility birth and ANC visits) (59). One of the main findings across all country's regions was that the uptake of four or more ANC visits and facility births remained suboptimal. Even considering some remarkable improvements, in 2017-2019, uptake of four or more ANC visits was of 56% and of facility birth 49%. Moreover, health regions where PIMI-I was first implemented had a lower uptake of ANC visits and facility birth in comparison with regions where PIMI-I was implemented in 2017-2019. Perinatal mortality remained high at 8% all trough PIMI-I and during the second phase of PIMI-II. Not only uptake of MCHS was lower than anticipated, but the last aspect underlies that the increased uptake of MCHS was not correlated with, in this case, decreased perinatal mortality, indicating the existence of other aspects of care that impact mortality (59). Nevertheless, mortality of women of fertile age tended to decline throughout PIMI's operation, being 14% lower in 2017-2019 (PIMI-II) than in 2011-2013 (pre-PIMI) (59).

Despite these efforts, in 2021, Guinea-Bissau's coverage of reproductive, maternal, newborn, and child health (following the WHO's Universal Health Coverage sub-index) was measured at 60, while Portugal and Denmark achieved coverages of 92 and 94, respectively (69).

1.4 Demand and supply-side characteristics associated with coverage of ANC visits, childhood vaccination, and facility births: what is already known

For a comprehensive understanding of this chapter, it is essential to first delve into the recurrent concepts of demand and supply-side in MCHS. The framework developed by Levesque et al (70) is helpful in deconstructing the complex pathway of accessing health care. The authors consider that access to health services result from the convergence of a person's characteristics, households, social and physical environment but also from the health system and health provider characteristics (70). Therefore, the different dimensions to access health services are captured in the characteristics of the demand-side (the population) and of the supply-side (the services) (70, 71).

Supply-side characteristics are included in five dimensions of accessibility of services: *approachability* (i.e. transparency, outreach from health services), *acceptability* (i.e. cultural and social factors that determine the possibility for people to accept aspects of services (i.e. sex, norms, belief of providers), *availability and accommodation* (i.e. physical space, geographical location, hours of opening, accommodation), *affordability* (i.e. indirect or direct costs), and *appropriateness* (i.e. technical quality, interpersonal quality of services). In turn, demand-side characteristics are included in five abilities that influence accessibility of services, and interact with the supply-side dimensions: *ability to perceive* (i.e. health literacy and knowledge that allow the perception of the need for care), *ability to seek care* (i.e. personal autonomy and capacity to seek care), *ability to reach* the health facility (i.e. personal mobility and availability of transportation), *ability to pay* for health care (i.e. the capacity of generating income and pay for health services without catastrophic expenditure) and *ability to engage* in health care (i.e. participation of the patient in decision-making and treatment decisions, health literacy, self-efficacy) (70). Other authors assert the need to address the demand and supply-side barriers concomitantly to correctly undertake health care challenges (72).

1.4.1 Supply-side: health professional's characteristics as mediators for the use of maternal and child health services in LMIC

Health workers knowledge and skills, health workers motivation and perception of patients' demands and health workers understanding of work responsibilities have been shown as determinants of good quality performance (73). These features are considered to interpret the quality of care and, thus, the uptake of MCHS, as its uptake is possibly linked to the quality of the care provided.

i) Health professional's motivation, behavior, skills, and relationship with the patient

Negatively perceived attitudes or behaviors, lack of motivation, or unequal power dynamics have been described as characteristics that act as barriers to women choosing facility births, ANC, or vaccination for their children (74, 75, 76, 77, 78). Indeed, health professionals in some contexts refer to an existing hierarchical superiority in comparison to their own patients, justifying abuses of authority (79).

Yet, patient attitudes and behaviors can trigger staff negative attitudes. For example, it has been described in a systematic review that, in the African setting, doctors, midwives, and nurses complain that women presented themselves late for ANC visits or delivery, falsely accused providers of mistreatment, or did not comply with medical recommendations. Such actions can lead to frustration of healthcare providers and, thus, to verbal abuse and scolding of these patients (79).

ii) Health professional's perceptions and judgements

Health staff beliefs or perceptions also play a role in their everyday work. A qualitative Saudi-Arabian study recounts that health professionals would be selective with whom they cared for, discarding women that did not value ANC visits, or if the mother had lower education (80). In fact, a systematic review confirmed that healthcare providers held prejudices towards certain attributes of patients, including socioeconomic status, educational attainment, age of mother (affecting more women of older age or teenagers; these last ones

being particularly mocked or abused), or ethnicity, resulting in discrimination or negative behaviors towards women and children (79).

While ethnicity as an explanatory variable is widely analyzed in different studies, relevant studies do not focus on the consequences of the disparity between the ethnicity of the health worker and their patients, with evidence being available only for in high-income countries, related to delay in children vaccination (81).

1.4.2 Supply-side: health center's characteristics as mediators for the use of maternal and child health services in LMIC

Frameworks that evaluate the quality of care in maternity services (66, 67), split it in two dimensions: *provision of care* and *experience of care*. In the first, human and physical resources (e.g., qualified staff, staff attitudes, staff training, availability of essential drugs, the layout of wards, number of beds, structural features, state of support services such as electricity or running water, timeliness of salary payments) and referral systems' characteristics (e.g., timely admissions, waiting times, availability of transport and driver) are included, among others. Once again, despite being developed to interpret quality of care, these aspects may also influence coverage of MCHS, as quality of care is related to uptake of MCHS.

i) Lack of human resources and waiting times

Staffing shortages, as well as great affluence of patients attending the health facility, can create delays, which can be demotivators for facility deliveries and uptake of ANC visits (82). There have been previously reported situations when there was an excess of people waiting at the health facility and some women arriving for delivery were denied care (83). Overcrowding is also mentioned as a deterrent to full vaccination in children in countries with a substantial volume of children per health facility (84). An overburdening of health workers can be connected to absenteeism, stress, and lack of motivation (85, 86), in turn affecting waiting times, access, and quality of MCHS (87, 88).

ii) Working schedules, availability of supplies and medicines, and affordability of prices

Working schedule of health facilities can be a determinant of maternal and child healthcare access and outcomes. In a systematic review about the African health care setting, women pointed out that, when trying to access obstetric care, often health centers were not open during nights and weekends, and that shortage of medicine and equipment occurred, even when the facility was open (89). Limited service hours or time schedules not adapted to women's working hours are complemented as a barrier to full vaccination in children (75, 77, 78, 82).

Previous studies also showed that when (clean) equipment (90), supplies and medicines (89, 91) were available, women did prefer to give birth in a health facility, instead of using a Traditional Birth Attendant (TBA) at home (90). This is also true for uptake of ANC visits, since the lack of maternal supplies or technical resources (e.g. ultrasound machines) limit women's attendance (74, 89), and for vaccination in children, as stock-out of vaccines discouraged parents from returning to health facilities to get their children vaccinated in another time (77, 78).

Not only the lack of essential medicines is reported as a demotivator but also, when existent, the high charged prices (82). The availability of vaccine and affordability of costs at the time of health facility visit is associated with higher odds of full vaccination (92). Another aspect that comes with affordability is that, even if it is the case that there are no fees for vaccines (78, 93), medicines or maternal services provided (82), indirect costs such as income loss or transportation costs prevail (94, 95). These sometimes prohibitive costs of health services were often coupled with the unpredictability of fees (82).

iii) Health facilities' infrastructure

Privacy is a health service characteristic valued by women. Lack of private labor wards in health facilities could be conducive to choosing to deliver at home (90, 96) or to not attend ANC visits (97). This was overall common, as women often reported an inadequate facility infrastructure with overcrowded wards, without specified delivery rooms, and with the possibility of having men and women distributed across the same wards (83). Poor

infrastructure was a recurring theme alike in two systematic reviews focused on low-income countries: lack of electricity, running water, or buildings lacking repair were a disincentive to seek maternal services (75, 89).

iv) ANC visits as an opportunity for health education and motivator for facility births

ANC visits are associated with higher use of facility-births (53, 76, 98) and both with a higher probability of a child being fully vaccinated (99). The use of health facilities to deliver is often connected with knowledge about complications that could arise during birth and this learning can be acquired from exposure to health information during ANC (100).

Often, a reproductive health card (also commonly called ANC card (101), where information about the development of pregnancy is registered) is given to pregnant women during these visits. In a meta-synthesis of qualitative studies in LMIC, women reported that if they showed at the health facility for delivery but did not possess a reproductive health card, health professionals would refuse assistance. For some women, this meant that they only needed to attend one ANC visit in order to obtain the card (101).

1.4.3 Supply-side: village geographical characteristics as mediators for the use of maternal and child health services in LMIC

The distance between the health facility and the place where the woman and child live is one village characteristic included in the supply-side determinants. A smaller distance to health facility is associated with increased probability of facility deliveries (96, 102), fully vaccination in children (77, 78, 93, 99), or higher uptake of ANC visits (74). It is common in these contexts that greater distances to health facilities are also coupled with lack of (affordable) transportation (89, 103).

1.4.4 Demand-side: child and maternal characteristics as mediators for the use of maternal and child health services in LMIC

Significant determinants from the demand-side associated with four or more ANC visits, include maternal educational attainment, media exposure, maternal age, child's birth order (104), husband's education, and planned pregnancy (105). Urban or rural residence, maternal and paternal education, maternal occupation, wealth index, media exposure, and contraceptive use are associated with eight or more ANC visits (106). The child gender can also play a role: in a Pakistani study, knowing that the child was male increased parent's desire to utilize ANC services, and women perceived them as being of a higher quality (107). Predictors of facility births include maternal socioeconomic factors, maternal education and health literacy, male involvement in decision-making, maternal exposure to media, ANC attendance, and cultural factors (100, 108). Women with higher parity were less likely to receive early ANC and to attend the recommend number of visits, as well as delivering at a health facility, since risk perception reduces with each successful delivery at home (75, 80, 98, 105, 109).

Positive predictors for full children vaccination include four or more ANC visits, socioeconomic factors as maternal and paternal education, and maternal media exposure (99, 110, 111, 112). A significant association between birth order and full vaccination was also found, with the odds of being fully vaccinated decreasing as the number of children in the family increased (99).

Woman's perception of quality of care can influence the likelihood of using ANC, delivering at a health facility, or vaccinating their children. Components of *experience of care*, as the human and physical resources as perceived by women (e.g. satisfaction with infrastructure, cleanliness, contact time with qualified staff, percentage of female health professionals, staff qualification), the cognition (e.g. percentage of women that were given accurate information or that were able to understand information given, previous explanation before procedure, percentage of women who understand the probable reason for poor outcome) and the respect, dignity, and equity within care (e.g. percentage of women that report respectful treatment, reported practices that are culturally offensive to women, percentage of women reporting

financial constraints) must be addressed to promote - or evaluate - the quality of care in maternity services (66, 67).

Indeed, if women perceive quality of the care as unsatisfactory, then it negatively impacts their uptake of MCHS services, and consequently the coverage of MCHS, regardless of the health center or the health professional's characteristics (113). It is also evident, when reviewing the literature, that women's perception of care is sometimes not contemplated or does not match the health professionals' perception of care (80).

Linking this perspective with the importance of the health professionals behavior and relationship with patient (1.4.1 *i)*), health professional's lack of knowledge or impaired ability to communicate has been associated with dissatisfaction with ANC visits (80) and under-vaccination of children (77, 78). Participants from two qualitative studies in Uganda and Saudi Arabia refer to procedures during ANC visits being done without any explanation (74, 80), occasionally coupled with the fact that the service was provided by students, unexperienced people, which further bolstered untrustworthiness and displeasure with the health service (114). Women often expressed their apprehension about the suboptimal training or experience of health workers, stating that they do not demonstrated the necessary skills to address pressing needs (82, 89), prompting them to deliver at home instead (76). Furthermore, previous experience of unskilled birth attendance can be also be linked to negative perception of care (89), or, on the contrary, no history of stillbirth can be associated with positive perception of care and higher satisfaction with ANC services (97, 114).

A systematic review on the use of maternal services reported the existence of serious events, such as lack of respect and mistreatment of women by health workers or even the discouragement of patients from using maternity services (89). Women recounted being abandoned or neglected during consultations or critical situations or being scolded or abused if they did not have a reproductive health card. Adding to these findings are women's descriptions of refusal from health workers to provide care or treatment, assist with the use of toilet facilities, or provide medication. These refusals seemed to be linked to increased morbidity and mortality of women and children (79).

1.5 Demand and supply-side characteristics associated with coverage of ANC visits, childhood vaccination and facility births: what is already known in Guinea-Bissau

Publications from studies developed in Guinea-Bissau found significant associations between higher maternal socioeconomic status, namely higher educational attainment, with increased odds of facility births (115) and with children vaccination status (116). A PIMI report found that maternal socioeconomic status was associated with a higher uptake of ANC visits and facility births, and that a higher uptake of ANC visits was associated with a higher likelihood of facility births (59). A more recent PIMI study found that out-of-pocket payments and long distance to health facilities acted as great deterrents for women when choosing place of delivery, although benefits of facility birth being widely acknowledged (117). Other qualitative study conducted in the country further explored the commercialization of MCHS, where health professionals interviewed referred to informal fees being charged for several services and goods (e.g., fines for not delivering at the health center, drugs) (118). These fees were also reported as being arbitrary and unreasonable, and used to buy medicine, maintenance repairs or hiring staff (118).

From the grey literature, reports with descriptive information were found (1, 17). One specific qualitative World Bank report where the demand-side constraints to MCHS were assessed, developed an empirical framework to explain the demand and supply barriers to improve the coverage of MCHS in Guinea-Bissau (34). The authors accentuate the poor technical quality, unpredictable and high costs, poor access to health facilities and traditional practices, a weak training of health professionals, shortage of health workers and inadequate supply chain, scarce public funds and delay in payments, and deficient referral systems.

There is a clear paucity of studies on the determinants associated with the use of MCHS from the supply-side perspective, as only one qualitative study was retrieved where Bissau-Guinean women reported that geographical distance to health facility and out-of-pocket payments were a barrier to facility birth (117), and other that also referred to unpredictable fees being charged at the health centers for the use of diverse MCHS (118). No other studies

statistically assess which health center characteristics (or even individual health professionals' characteristics) were associated with uptake of facility births, full childhood vaccination, and four or more ANC visits. Nevertheless, Levesque et al (70) framework of accessibility to health care, help to inform the design of the conceptual framework of the use of MCHS in this setting (Fig. 4).

Factors that influence the use of MCHS in Guinea-Bissau exist in different, complex, and interactive dimensions, some of them already subjected to prior quantitative or qualitative research in this country and in the African context. That is, we hypothesize the existence of characteristics related to (1) the supply-side, as in, (i) health professionals' socio-demographic and job-related characteristics, (ii) health centers' organizational characteristics, in which health professionals are incorporated, and (iii) health regions' characteristics, in which both health professionals and health centers are incorporated; and also characteristics related to (2) the demand-side, as in (i) child socio-demographic characteristics, (ii) maternal socioeconomic, socio-demographic, and obstetric characteristics, in which the child is incorporated, and iii) community characteristics, in which both the child and mother are incorporated.

From the (1) supply-side, the (i) *health professionals' socio-demographic and job related characteristics* include ethnicity, age, cadre, sex, work satisfaction, and relationship with patient, the (ii) *health centers' organizational characteristics,* include type of health center, working schedule, charged fees, periodicity of consultations, distribution of incentives, availability of medicines/vaccines/working instruments/evacuation vehicles, and quality of infrastructure, and the (iii) *health regions' characteristics* include regional guidelines, geographical distance to health center, population per health center, and number and/or effectiveness of community workers. From the (2) demand-side, the (i) *child socio-demographic characteristics* include sex, birth order, place of birth, season of the year (at birth), the (ii) *maternal socioeconomic, socio-demographic, and obstetric characteristics* include socioeconomic level and education, age, ethnicity, household size, ANC attendance, history of stillbirth or of previous facility delivery, and the (iii) *community characteristics* include traditions, cultural beliefs, and gender roles. Both supply and demand-side converge to influence women and child's use of MCHS (70) and can be seen in macro levels (e.g.

health region and community's characteristics) or micro-levels (e.g. health professional and child and maternal's characteristics).

This framework tries, thus, to suggest the factors from the demand and supply-side that impact the uptake and, at a population level, coverage of facility births, four or more ANC visits and full childhood vaccination. Yet, as shown, the evidence supporting the applicability of this framework in Guinea-Bissau is still scarce, especially assessing both perspectives, supply and demand. While some factors are not easy to assess in quantitative studies, namely the cultural perspective of individuals or of the society they pertain to, or attitudes of patients and staff, several others can be studied, such as organizational health center characteristics, geographical characteristics, and child and maternal socioeconomic, socio-demographic, and obstetric characteristics. This study proposes to identify which of these demand and supply-side factors are associated with the uptake of four or more ANC visits, full childhood vaccination and facility births and, consequently, with coverage of these indicators. Additionally, data collected at the health centers allowed the characterization of the quality of care from the health professionals' perspective, as this is also theorized to be relevant to the uptake of MCHS in the Bissau-Guinean context.

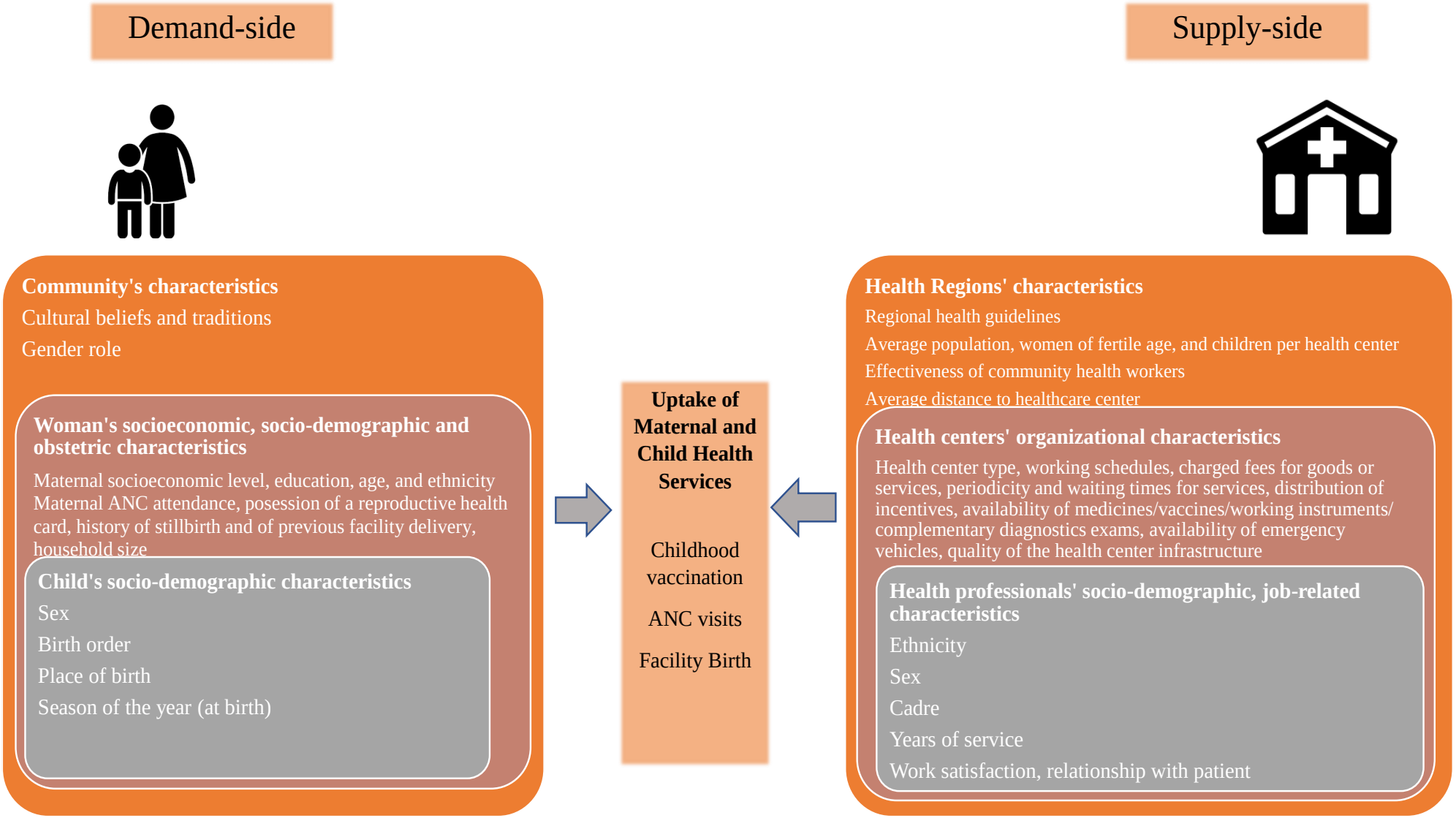

Fig. 4. *Conceptual framework for the uptake of childhood vaccination, ANC visits and facility births in Guinea-Bissau*

1.5.1 Research question and study aims

The country's history of political instability contributed to a current deficient infrastructure and human development (1). As a result, the national health system struggles to provide adequate care for its citizens due to a lack of (trained) human resources, logistics chains, and sufficient main and auxiliary infrastructures (1, 10). Women and children in particular are one of the most vulnerable groups, due to the fragility of physiological processes such as pregnancy, birth and child's development of their immune system (119). Such vulnerability is further exponentiated in countries such as Guinea-Bissau, owing to high fertility ratios, low maternal literacy, gender equity (4), and agency (119). Consequently, MMR and U5MR remain high and women and children's opportunity for longer and healthier lives continues to be refused (120). As women of fertile age and children constitute (or may constitute) a great proportion of body and mind-able human resources for Guinea-Bissau's development, investing in their well-being and longevity is of the highest priority.

Adequate and accessible MCHS that include childhood vaccination, ANC visits and facility birth are aimed at tackling these public health issues. Programs that proposed to strengthen MCHS, such as PIMI, are implemented nationwide. By eliminating fees, providing supplies, and professional training, it was expected that access, uptake, and coverage of MCHS would increase, and maternal and child mortality, therefore, reduce. However, coverage indicators of these services are still unsatisfactory (59) and maternal (1), neonatal, infant, and under-five (61) and perinatal mortality (59) were not reduced. It is apparent that barriers to the uptake of MCHS in Guinea-Bissau are still existent and may consist of constraints from the supply-side (e.g., health professionals, health centers and health regions' characteristics) or from the demand-side (e.g., child, maternal and community's characteristics).

As previously discussed, to reduce mortality, increasing coverage of MCHS alone may not be a sufficient solution (1, 59). Increase in coverage must be coupled with increase in quality yet, the methodology to study coverage of MCHS and the factors that lead to the uptake of these services, is not the same as the one to study quality. Though we recognize the potential influence of the latter, this research can only focus on the determinants that could increase the uptake and impact coverage of MCHS.

Little is known about the perspectives of the supply side regarding the uptake of MCHS in Guinea-Bissau. Health center characteristics, such as infrastructure conditions, availability of medicine, consultations, diagnostic exams, distribution of incentives, working schedule, among others, and geographical characteristics such as distance to health center, must be analyzed in relation to uptake of MCHS. The simultaneous analysis of the association between child and maternal characteristics and the uptake of these services, or corroborating the evidence already found, is a needed complement to understanding Levesque et al. (70) framework and adjust it to this country, and contribute to understand the access and coverage of MCHS in LMIC.

Guinean guidelines that focus on improving factors both related to the supply and demand-side are insufficient, and tailored interventions can only be settled once there is an understanding of what obstacles exist and strongly affect women and children's use of MCHS, especially when resources are sparse. This study expects to fill this gap in Guinea-Bissau, aiding stakeholders and policy makers to identify and reinforce possible facilitators and to address the most common unnoticed and unresolved barriers to maternal and child healthcare use.

Thus, this study follows the research question:

Which characteristics of the health centers, alongside underlying village geographical and child and maternal determinants, are reflected in a greater uptake of facility births, four or more ANC visits and full childhood vaccination?

The current study has the following main objective:

- ✓ To assess which characteristics from the demand and supply side are associated with four or more ANC visits, facility births, and full childhood vaccination in the Bissau-Guinean regions of Biombo, Oio and Bafatá.

The three secondary objectives are:

- ✓ To assess which health center and village geographical characteristics are associated with four or more ANC visits, facility births, and full childhood vaccination in the Bissau-Guinean regions of Biombo, Oio and Bafatá.

- ✓ To assess which child and maternal socioeconomic, socio-demographic, and obstetric characteristics are associated with four or more ANC visits, facility births, and full childhood vaccination in the Bissau-Guinean regions of Biombo, Oio and Bafatá.
- ✓ To describe health professionals' socio-demographic and job-related characteristics posited to be involved in quality of care in MCHS in the Bissau-Guinean regions of Biombo, Oio and Bafatá.

2. Methodology

2.1 Study design

This is a cross-sectional study involving primary data collected at health centers and secondary data related to women and children from the Bissau-Guinean regions of Biombo, Oio and Bafatá from the BHP's HDSS.

2.2 Description of data source and study's settings

2.2.1. Data from the HDSS

Secondary data for this research were extracted from the data of the rural HDSS, which collects data since 1989-1990. The HDSS follows a cohort of women of reproductive age (13-49 years) and children below 5 years of age. Clusters were selected based on recommendations from the Expanded Programme on Immunizations for surveys of immunization coverage, where the chance of being selected should be proportional to the population size. Twenty clusters of 100 women per region were originally selected and if the village had fewer than 100 women, the closest village was included as well; a third village was selected if a sample of 100 women was not reached.

From 2006 onwards the HDSS is covering 20 randomly selected clusters in the regions of Oio, Biombo, Gabu, Cacheu, São Domingos, Bafatá, Tombali, Quinara, Bubaque (10 clusters), and Bolama (12 clusters). Hence, in its present form, the rural HDSS consists of 182 village clusters (Fig. 5).

When a woman is enrolled in the HDSS, data on ethnicity, age, educational attainment, socioeconomic factors, and obstetric history is registered. In the following visits, updates on the pregnancy status, births and miscarriages are collected; if the woman is pregnant, not only the child is registered automatically in the HDSS, but the use of ANC services and gestational age, among others, is asked.

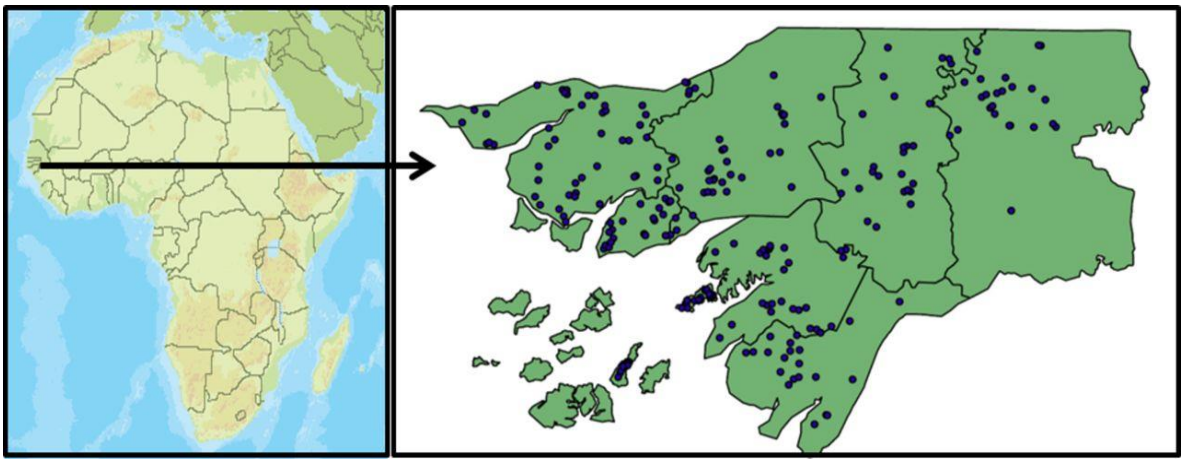

***Fig. 5**. HDSS clusters distribution across Guinea-Bissau (121)*

After delivery, information on pregnancy outcomes and place of birth of the child is gathered. The child is followed until turning 5 years old, moving outside the villages covered by the HDSS, or until their death. Children under 5 years who migrate to these villages are also followed. Among other data, child vaccination status and dates of vaccinations are collected.

Data is collected through experienced fieldwork assistants, and loss to follow up is relatively low since family members in the village can also supply information (essential in a population with high mobility) (121).

For this study, secondary data collected from the HDSS was used for the outcomes – full childhood vaccination, four or more ANC visits, and facility births – and for child and maternal characteristics. The population base for assessing coverage of childhood vaccination includes children born between 1st of January 2020 and 1st January 2021 and whose uptake at 12 months is assessed between 12-23 months (i.e., last date of follow up is 1st January 2023); and the population base for assessing coverage of ANC visits and facility birth includes children born between 1st January 2021 and 1st January 2023. We only used data from mothers and children living in the regions of Oio, Biombo and Bafatá as data from the other regions related to the period between 1st of January 2020 to 1st January 2023 were not as complete. Also, these three regions considered rural areas have a large variability coverage of MCHS (59). Additional secondary data on the coordinates of the reference health center of HDSS's villages were requested from UNICEF, to allow the estimation of distances.

2.2.2. Data from health centers

Primary data was collected through structured interviews and questionnaires at 35 health centers. Data was collected during a 10-week period from end of January to mid-April 2023. Face-to-face questionnaires were applied to the person responsible of each health center and the face-to-face structured interviews were conducted with at least two health professionals present at the time of the interview at the health center. Please refer to *Supplementary Information 1* for a more detailed explanation of how the questionnaires and the structured interviews were conducted, as well as the paper version of these instruments (the questionnaires and the structured interviews, on the field, were tablet-based).

In this study, we presumed that women and children use their reference health center. Data about which health facility was used by the woman and child was not available, and collecting individual data or consulting all regions health facilities paper records would require a large time investment. Also, HDSS villages are linked to Sanitary Areas and each Area usually only has one reference health center. Thus, women and children probably use MCHS provided from the health center located in the Sanitary Area identified in the HDSS. In two Sanitary Areas a hospital is available, besides a health center. Considering the potential bias since women from these two Areas give birth at the hospital, and hospitals were not a unit of analysis, we did not use data from these two Areas when assessing the determinants associated with facility births. For childhood vaccination and ANC consultations all women must go the health center. When a Sanitary Area has a satellite health center besides the main health center, we assumed that the woman/child would still use the reference health center for MCHS as services in these satellite centers are offered inconsistently and staff and other resources are shared.

2.3 Research participants, eligibility, and inclusion criteria

As this study set out to assess the impact of both the supply and demand-side on the coverage of childhood vaccination, ANC visits and facility births, inclusion criteria depended on the characteristics of health centers – supply-side – and characteristics of HDSS's research participants – demand-side.

Regarding the supply side, we collected data about 35 health centers, by interviewing the person responsible for its management. This responsible also provided a demographic characterization of the health professionals who worked at his/her health center. In addition, 88 health professionals gave their insight on the quality of care from the providers' perspective. All of these data were primary. Therefore, all health center's responsibles were considered eligible for the study, as their role as chief nurses and/or Sanitary Areas' responsible implied that they could provide detailed information on health centers and its health professionals' characteristics. Regarding health professionals, to be eligible for the structured interviews, health workers had to be directly involved with the provision of the health service to the woman and child, and thus, professionals exclusively dedicated to administrative work were not selected. Only those who gave informed consent were included.

The second group of research participants is linked to the demand-side, as in the women and children targeted by MCHS. This group of research participants served two purposes: 1) to provide the child and maternal socioeconomic, socio-demographic, and obstetric characteristics (i.e., independent variables) that potentially affect uptake of these services and 2) to determine the actual uptake and consequent coverage of these services, outcomes of the study – full childhood vaccination, four or more ANC visits and facility births. These data were secondary. The number of research participants from the demand-side, the children, and their mothers, will vary depending on the outcome, being described in more detail in the next sub-chapter.

2.4 Description and operationalization of variables

Outcome variables

This study assesses three dependent variables, all originating from the HDSS.

- ✓ **Coverage of childhood vaccination**

The population base for assessing full childhood vaccination status includes children born between 1st of January 2020 and 1st January 2021.Vaccination status at 12 months was assessed in children aged 12-23 months, taking into account the Bissau-Guinean vaccination schedule (see chapter 1.3.3), excluding OPV-0 at birth, as for this vaccine we follow the WHO recommendations (three doses of polio vaccines) (122) instead of Guinean guidelines (which include four). For a child to be eligible for this outcome, he/she must fulfill the following requirements:

a) the vaccination card was inspected by an experienced field assistant between the ages of 12 to 23 months

b) children were alive (at the very least) at the time of the first visit where a vaccination card was inspected after completing 12 months

c) children did not leave the cohort before completing 12 months of age

d) if a child had several visits between 12-23 months where the card was inspected, only the date of the first visit was used.

This variable was thus, binary: a child was either fully vaccinated or not fully vaccinated. The flowchart of the children available for this outcome details how the baseline of this cohort was reached *(Supplementary Information 2).*

- ✓ **Coverage of ANC visits**

The population base for assessing the uptake of four or more ANC visits includes children born between 1st January 2021 and 1st January 2023. This outcome specifies the number of ANC visits during pregnancy. The number of visits is collected using the inspection of the pregnancy card.

If a card was not available for inspection, then the woman's recount of how many visits she has had, is used as an alternative. For a child to be eligible for this outcome, he/she had to be resident in the study area before completing 12 months of age (when collecting data for the HDSS, in the case a child enters the cohort after completing 12 months, no information about ANC is asked nor the pregnancy card is inspected). In case of multiple births, all the deliveries from the same women were included. When neither card was available nor the woman recalled the number of ANC visits, then this variable was coded as unknow, and children with unknown number of ANC visits were thus excluded from the analysis. This variable is binary: either the mother of the child, while pregnant, had four or more ANC visits or less than four ANC visits.

- ✓ **Coverage of facility birth**

The population base for assessing coverage of facility births is the same baseline cohort used to study the coverage of ANC visits. It includes children born between 1st January 2021 and 1st January 2023 and follows the same eligibility criteria. The children's place of birth was obtained directly from their mothers. If the mother could not provide information on their child's place of birth, then this variable was coded as unknow and these children with unknow place of birth were excluded from the analysis. This variable is binary: the child was either born at a health facility (health center/hospital) or not born at a health facility (home/other).

Explanatory variables

These corresponded to the supply-side variables - health center's characteristics (Table 1) and the village geographical characteristics (Table 2) - and the demand-side variables - the child-maternal socioeconomic, socio-demographic, and obstetric characteristics collected through the HDSS (Table 3).

Data regarding the health professionals' socio-demographic and job-related characteristics were also collected. These variables were not used in the statistical analysis, since the health professionals interviewed would not be representative of all the population of health professionals working at the health centers. These variables were rather collected in order to

deliver a more detailed portrayal of the health professionals as individuals that provide care and are inserted in the health center and regional macro-levels (Table 4).

Table 1. *Health centers' characteristics possible predictors of full childhood vaccination, four or more ANC visits, and facility births*

Health centers' characteristics			
	Uptake		
Primary data collected through questionnaires to the person responsible of each health center	Vaccination	ANC	Facility birth
Type of health center A, B, C	**X**	**X**	**X**
Emergency care (nº of days/week) 0,7		**X**	**X**
Services costs (XOF)⁜ 0, 500, 1,000	**X**	**X**	**X**
Card costs (XOF)⁜ Reproductive Health Card, Tetanus card, Infant Health card	**X**	**X**	**X**
Periodicity of consultations (nº of days/week) 5, 7	**X**	**X**	
Waiting times (hours) 0, <2, >=2	**X**	**X**	**X**
Distribution of incentives Mosquito tents, Medicines, Post-partum kit, Others	**X**	**X**	
Availability of essential working instruments *Supplementary Information 1*▲		**X**	**X**
Availability of complementary diagnostic exams *Supplementary Information 1*▲		**X**	**X**
Availability of essential groups of medicines ₸ *Supplementary Information 1*▲	**X**	**X**	
Emergency evacuation vehicles Yes, No		**X**	**X**
Type of emergency vehicle Ambulance, motorcycle		**X**	**X**
Cost of evacuation transportation (XOF)⁜		**X**	**X**
Health center performs ultrasound Yes, No		**X**	**X**
Quality of infrastructure ♠ Very bad, bad, reasonable, good, very good	**X**	**X**	**X**
Pre/post-partum room exclusive for women Yes, No			**X**

Notes:
*The "X" indicates that the variable was assessed in relation to the outcome

⅀ XOF-West African CFA franc: 500 XOF (0.76 EUR); 1000 XOF (1.52 EUR)
₸ Defined based on WHO's list of essential medicines (117) and adapted to the Bissau- Bissau-Guinean context, focusing on antihelmintics,analgetics,contraceptives,antibiotics,antimalarials, and antiretrovirals. Missing essencial medicine is defined as at least one medicine per group of essential medicines missing (e.g. Paracetamol, out of the analgesics essential group of medicine, absent from the facility; or, for instance, children-dosed Paracetamol missing)
▲ For information regarding the total list of essential working instruments, complementary diagnostic exams and essential group of medicines refer to *Supplementary Information 1*
♠ Quality of infrastructure is regarding sanitary conditions, physical infrastructure, and source of electricity. Both the person responsible for each health center and the health professionals employed there were asked about their opinion, in order to contrast answers. For the regression analysis, each category of this variable was given a number and the mean of answers per health center was calculated and the health center further classified according to its' quality of infrastructure

Table 2. *Village geographical characteristics possible predictors of full childhood vaccination, four or more ANC visits, and facility births*

Village geographical characteristics			
	Uptake		
Secondary data obtained through UNICEF and the HDSS	Vaccination	ANC	Facility birth
Distance to health center (km) ♦ < 2km, >=2 to 5km, >=5 to 8km, >=8km	**X**	**X**	**X**

Notes:
♦ Calculated as the geographical distance from the HDSS village to the reference health center of the Sanitary Area using UNICEF's health center coordinates and HDSS's village coordinates

Table 3. *Child-maternal socioeconomic, socio-demographic, and obstetric characteristics possible predictors of full childhood vaccination, four or more ANC visits, and facility birth*

Child and maternal socioeconomic, socio-demographic, and obstetric characteristics			
Secondary data obtained through the HDSS	**Uptake**		
	Vaccination	ANC	Facility birth
Child's socio-demographic characteristics			
Sex Male, female	**X**	**X**	**X**
Place of birth Health facility, home, other	**X**		
Birth order 1st, 2nd or 3rd,4th or 5th,>=6th	**X**	**X**	**X**
Season of the year ♯ Dry season, rainy season			**X**
Maternal socioeconomic, socio-demographic, and obstetric characteristics			
Socioeconomic level ₸ Level 0-2, Level 3, Level 4, Level 5	**X**	**X**	**X**
Education (years) No formal education, >=1 to 4, >= 4 to 6, >=6, attended school, class unknown	**X**	**X**	**X**
Age (years) <14, >=14 to 19, >=19 to 25, >=25 to 35, >=35	**X**	**X**	**X**

Child and maternal socioeconomic, socio-demographic, and obstetric characteristics (continuation)			
Secondary data obtained through the HDSS	Uptake		
	Vaccination	ANC	Facility birth
Maternal socioeconomic, socio-demographic, and obstetric characteristics			
Ethnicity Fula, Mandinga, Balanta, Pepel, Manjaco/Mancanha, Other, Multi-ethnic	**X**	**X**	**X**
Household size ┼ < 3 children, >=3 to 6 children, >= 6 children	**X**	**X**	**X**
Known history of stillbirth ▲ Yes, No/Primigravidae		**X**	**X**
Known history of facility delivery♦ Yes, No/Primigravidae, Unknown			**X**
Mother attended at least one ANC consultation Yes, No, Doesn't know	**X**		**X**
Mother has a reproductive health card at first visit after birth Yes, No, Doesn't know			**X**

Notes:

Ŧ Socioeconomic level is determined by calculating the score based on the number of household items that the woman possesses**.** Women that possess a mobile phone, radio, generator/solar panel, an outdoor toilet, and hard roof receive a score of 5 – this is considered the highest socioeconomic level; women that lack all or almost all the mentioned household items receive a score between 0 and 2, being considered the lowest socioeconomic levels. For more information regarding composition of this variable please refer to Supplementary *Information 3*

♯ Season of the year at birth of the child

┼ Number of children the mother has in her care, either her biological or foster children

▲ There is evidence of underreporting of dead children compared to live children (123) and thus, it is not possible to assertively affirm that the mother never had a stillbirth; stillbirths, in the HDSS, can be confirmed retrospectively (before inclusion) and prospectively (after inclusion); therefore we categorized a known stillbirth as *yes*, if a stillbirth is reported either pre or pos-inclusion; and *no/primigravidae*, if it a stillbirth is not reported retrospectively or prospectively (and considering the mentioned uncertainty) or if the index child is the mother's first born

♦ Previous history of facility delivery, in the HDSS, can only be estimated prospectively; though parity before inclusion is known, place of birth of the child is not asked; therefore, we have the category *yes*, if a previous facility delivery of an older sibling to the index child is confirmed prospectively; *no/primigavidae*, if the mother had no previous birth and has only had confirmed children being born at home/other since inclusion OR if she is primigravidae with the index child being the first child; and *unknown* if the woman has had children before inclusion (whose place of birth is not available) and children registered after inclusion were born at home only

Table 4. *Health professionals' socio-demographic and job-related characteristics involved in quality of care in MCHS*

Health professionals' socio-demographic characteristics	
Primary data collected through questionnaires to the person responsible of each health center	
Cadre of health workers Nurse, Midwife, Physician, Laboratory technician/ Pharmacy technician, Others	**Ethnicity** Balanta, Pepel, Mancanha, Fula, Manjaco, Mandinga, Bijagós, Beafada, Felupe, Multi-ethnic, Others, Unknown

Sex Male, female	**Years on service (years)** <5, >=5 to 10, >=10 to 20, >=20
Job-related characteristics	
Primary data collected through structured interviews to the health professionals	
Quality of infrastructure Very bad, bad, reasonable, good, very good	
Frequency of the procedures' explanation Rarely, Sometimes, Almost always, Always	
Difficulties providing for women/children of different ethnicity Yes, No	
Type of difficulty experienced ₸ Communication (different language/woman struggling to understand), Acceptance of women's health behaviors (religion/culture), Both communication and acceptance of health behaviors	
Dissatisfaction with the work Never, Rarely, Sometimes, Almost always, Always, Doesn't know	
Demonstration of dissatisfaction ┼ Does not show his/her dissatisfaction, Reprimands the patient, Becomes irritated, impatient or screams at the patient Altered facial expression, Misses work, Charges for the free service	

Notes:

₸ Type of difficulty experienced is only answered by health professionals who answered affirmatively to "Difficulties providing for women/children of different ethnicity"

┼ Demonstration of dissatisfaction is only answered by health professionals who answered Sometimes, Almost Always or Always to "Dissatisfaction with the work"

2.5 Statistical analysis

Data were extracted and analyzed using Statistical Software for Data Science (STATA) version 17.0. Descriptive statistics, that included frequency tables and bar charts, were used to describe the health centers, health professionals, child-maternal characteristics, and coverage of childhood vaccination, facility birth and ANC.

We used a multilevel approach, as children can be nested in mothers, who in turn are nested in Family groups, Villages, Sanitary Areas and, at last, Regions. As such, children may share similar characteristics within the clusters, and the assumption of independence of observations is then violated, rendering the use of a traditional logistic regression invalid. A four-level mixed effect logistic regression was used to disentangle the between cluster heterogeneity and to identify the health center, village geographical, and child-maternal characteristics that may be associated with uptake of the studied MCHS. The Logical Explanations & Visualizations of Estimates in Linear mixed models (LEVEL) guideline to report multilevel data and analysis was followed throughout this study (124).

Thus, the first level of the multilevel model is the *Child - Level* and, from this level, we obtained the outcomes and the child-maternal variables. These variables were considered as having fixed effects, as it was not expected that these individual characteristics would have a different effect on the outcomes between clusters. The 'mothers' cluster was not considered, since not only maternal characteristics are captured in the first level but, for the vast majority of the mothers, they would have only one child in the study. The second level is the *Family group - Level* (in a village, families that share the same kitchen are considered to belong to the same family group) and, at this level, no variable was included. The third level is the *Village - Level*, from where village coordinates were obtained and the distance from village to the reference health center (village geographical characteristic), as a fixed-effect variable, calculated. The fourth (and final) level chosen was the *Sanitary Area - Level*, where fixed-effect health center variables were incorporated.

The Intracorrelation Cluster (ICC) of intercept-only models were determined using first, Sanitary Area as the highest level, and second, Region as the highest level; as Region presented an ICC of almost 0, Sanitary Area was then selected as the fourth level. The 2nd, 3rd and 4th cluster levels were modeled as random intercepts, allowing the assessment of the influence of the child's context in his/her's health outcomes. The random effects are assumed to be independent from each other. Furthermore, 1st level variables will be referred to as lower-level variables (child and maternal characteristics) and 3rd and 4th level variables as upper-level or contextual variables (distance to health center and health center characteristics). The multilevel diagram with the independent and dependent variables listed, as well as the cluster levels is presented below (Fig.6).

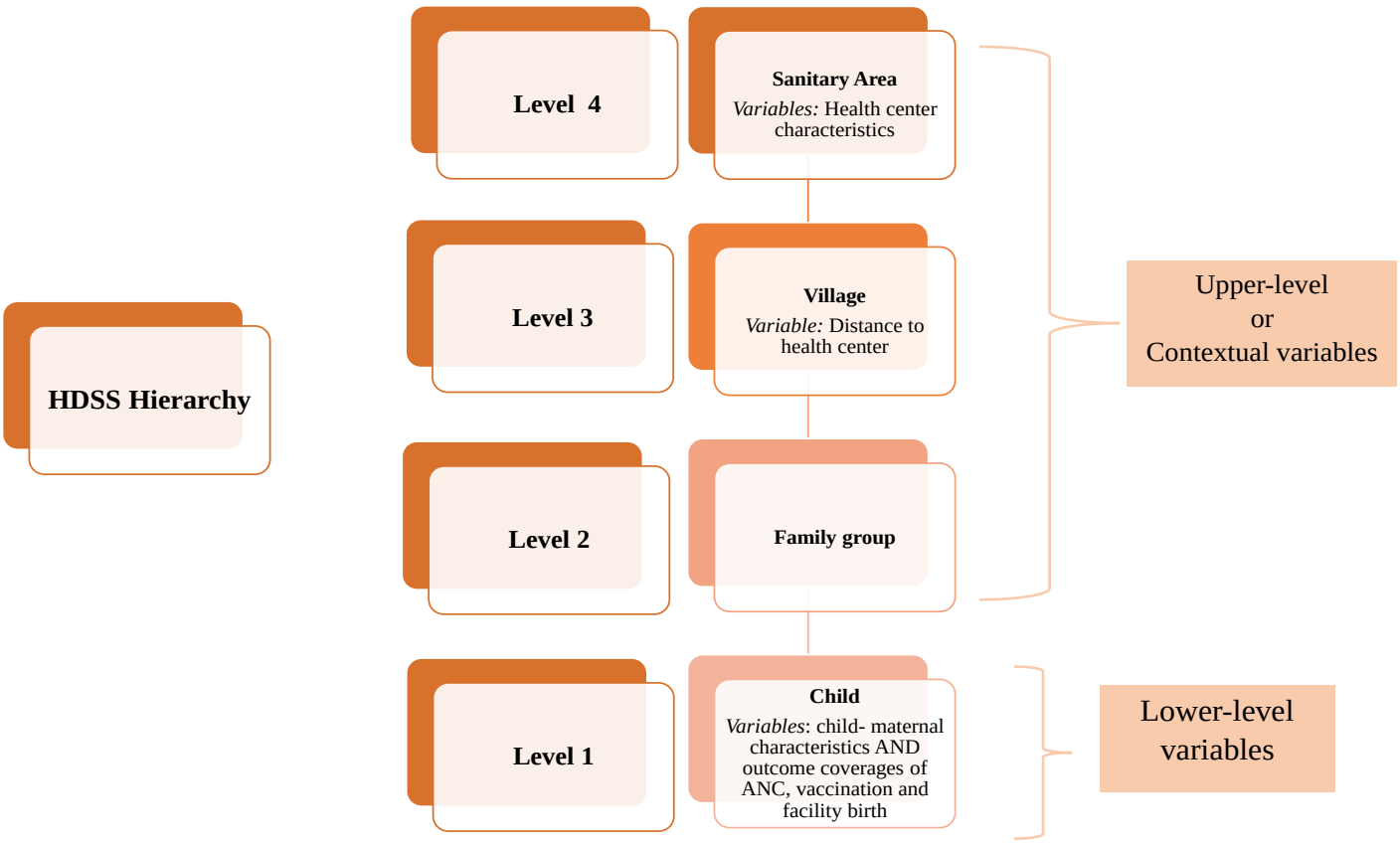

Fig. 6. *Multilevel diagram with independent and dependent variables, and cluster levels*

Four models for each outcome were then fitted after the identification of statistically significant variables in the multilevel bivariate regression. In the multilevel bivariate analysis, statistical significance was set at *p* value < 0.20; variables with at least one of the included categories with significant association, were included in the respective models; in

the multilevel multivariate regression, variables where *p* value <= 0.05 were considered significant. Model I is a "null" model with no independent variables, allowing the estimation of the contextual effect for further comparison (e.g., the probability of being fully vaccinated is a function of the *Sanitary Area, Village,* and *Family group - Levels*). In Model II, *Sanitary Area - Level* variables - health center characteristics - and *Village - Level* variables - distance to the reference health center - were fitted (e.g., the probability of being fully vaccinated is function of selected health center and village geographical characteristics, and of *Sanitary Area, Village,* and *Family group - Levels*). In Model III, *Child - Level* child and maternal variables were included (e.g., the probability of being fully vaccinated is function of selected child and maternal variables and of *Sanitary Area, Village,* and *Family group - Levels*). Model IV is then the final model, that incorporates all the *Sanitary Area, Village and Child - Levels* variables, estimating the probability of being fully vaccinated as a function of selected health center, village geographical, and child and maternal variables and on the *Sanitary Area, Village, and Family group - Levels.*

From the multilevel multivariate regression, the results of the fixed effects were expressed as Adjusted Odds Ratio (aOR) with a 95% Confidence Interval (CI%), and their interpretation considers the Model's hierarchical structure. For the multilevel bivariate regression, the results of the fixed effects were expressed as Unadjusted Odds Ratio (uOR) with an 80% CI. The random effects from each model were interpreted using three measures of variation. The first, ICC, measures the within-cluster variance, which ranges from 0 (no correlation in the intra-cluster observations, meaning that no variation in the outcome is among the upper-level variables but rather in the lower-level) to 1 (intra-cluster observations are totally correlated, meaning that no variation in the outcome is among the lower-level variables, but is rather found at the upper-level variables) (125). ICC based on the latent response was calculated using the formula $ICC = \frac{{\sigma^2}_{ijk}}{\gamma + {\sigma^2}_{ijk}}$, where $\gamma\,(variance\ of\ a\ standard\ logistic\ distribution) = {\pi^2}/{3}$ for mixed - effects logistic regression and ${\sigma^2}_{ijk}$ is the estimated variance of the random intercepts in each model (in this study's case ${\sigma^2}_{ijk}$ represents the sum of the variations of Sanitary Area *(i)*, Village within Sanitary Area *(j)* and Family group within Village within Sanitary Area *(k)*) (126). The second, Proportional Change in Variance (PCV) expresses the total variation attributed

to the child-maternal/health center/village geographical variables in each model, calculated as $PCV = \frac{\sigma^2{}_{ijk\,[Model\,I]} - \sigma^2{}_{ijk\,[Model\,II\,/III/IV]}}{\sigma^2{}_{ijk\,[Model\,I]}} \times 100\ \%$, $\sigma^2{}_{ijk\,[Model\,I]}$ being the variance of the initial model, and $\sigma^2{}_{ijk\,[Model\,II/\,III/IV]}$ being the variance of the models with more terms (127). And the third, the Median Odds Ratio (MOR), which is a measure that allows a direct comparison of the variance at the three cluster levels with the OR of the health center, village geographical, and child-maternal's characteristics, since it transforms the estimated clusters variance on the log-odds scale, to the OR scale. The MOR obtains the median value of the distribution of ORs by comparing individuals with the same values in the same covariates from two randomly chosen clusters, where one individual comes from a higher risk cluster and the other one from a lower risk cluster. MOR is calculated using the formula $MOR = \exp\left(\sqrt{2\,\sigma^2{}_{ijk}\,\phi^{-1}(0.75)}\right)$ with ϕ^{-1} being the inverse cumulative standard normal distribution function and σ^2 the cluster level variance. MOR can range between 1, in this case meaning no variation at the cluster levels or more than 1, where the higher the MOR the higher the cluster effect (127).

Model comparison was conducted using three measures of fit, the Akaike's Information Criterion (AIC) and Bayesian's Information Criterion (BIC) - where lower criterion suggests better model fit, albeit BIC penalizes model complexity more than AIC - (128), and the Area Under the Receiver Operating Characteristic (ROC) Curve (AUC). AUC simply measures the ability of the model of correctly discriminating individuals with and without the outcome and is obtained by plotting the true positive fraction, that is the sensitivity, against the false positive fraction, that is, 1-specificity. AUC values will range between 1, where the model perfectly discriminates, and 0.5, where the model performs random guesses (127). The model that better explains the outcome is going to be chosen considering the best values of both measures of variation and fit.

Presence of multicollinearity was tested using Variance Inflation Factor (VIF) and tolerance, where a variable with VIF > 5 and consequent tolerance of < 0.2 (129) was considered as showing multicollinearity and therefore eliminated from the model. None of the variables from the three outcomes showed moderate or severe multicollinearity.

2.6 Statistical power

We used data from the years of 2017-2018 for estimating power to demonstrate differences in coverage of ANC visits and facility birth. These pre-COVID-19 years are expected to be an appropriate starting point, with a variation within and between clusters similar to what we would expect in the current study.

As the reasoning for the power calculations for the two outcomes – facility births and ANC visits – is identical, only changing the estimated differences, coverage of facility birth will be used as an example. To estimate the power to demonstrate different effect sizes we used a suggested bootstrapping method (130). In this method, to estimate the statistical power, we simulated multiple data sets (based on the 2017-2018 data) that closely resemble the anticipated data under the alternative hypothesis of interest. We then conducted the planned statistical test on each simulated data set, and by calculating the proportion of simulations in which the null hypothesis is rejected, we obtained an estimate of the power (130).

In more detail, to estimate the statistical power, we followed four steps:

Step 1) Based on past HDSS data (2017-2018), we produced a data set with BHP cluster numbers, the number of Sanitary Areas and whether the individual child fulfilled the outcome criteria. For instance, for facility birth, children had to be registered in the study area before completing 12 months of age (as no information about facility birth is asked nor the pregnancy card is inspected for older children). If a child was born at a hospital/health center, they were considered a facility birth; if they were born at home/other they were considered as not being born at a health facility. Observations of missing facility birth status are not included.

Step 2) In the 2017-2018 data set, we randomized half of the Sanitary Area groups in an exposed group and half in an unexposed group, assuming a balanced group distribution. As

the Sanitary Areas were assigned to the two groups at random, we would expect them to have equal observed coverage (on average). We then set an expected difference and divide this into two components, *component A* and *component B* – e.g., 20% difference divided into, for instance, 4.5 (*component A*) and 15.5 (*component B*). For each Sanitary Area of each of the two groups, we set the overall coverage equal to the o*bserved coverage – component A* in **group 1** and *observed coverage + component B* in **group 2.**

Step 3) In each of the groups, for each child, the facility birth=1 status is assigned based on the probability of the cluster that the child is inserted and obtained in the previous step. This assignment is performed by sampling the individual child's status from a binomial distribution, the probability of observing facility birth=1 determined by the set probability. The set probability in **group 1** is *observed coverage – component A* and the probability in **group 2** is *observed coverage + component B.*

Step 4): We then compared the coverages using a multilevel mixed effects logistic regression model with Family group, Village, and Sanitary Area clusters as random effects terms, and registered whether the null hypothesis of no difference between the groups was rejected.

To obtain power estimates, we repeated steps 2 to 4 1,000 times. Based on the above power calculations, we will have around 87% power to demonstrate a significant increase in coverage of facility birth if the real difference is 20% and 84% to demonstrate a significant increase of coverage of ANC if the real difference is 17%.

For the outcome coverage of childhood vaccination, no power calculations were performed. Coverage at 12 months of age was estimated for children aged 12-23 months and born between 1st of January 2020 and 1st of January 2021. As we know, events such as the COVID-19 pandemic occurred in 2020 and national stock-outs of BCG and OPV also took place during 2020 and 2021 (131). The provision of MCHS could have been impacted (132) and consequently, vaccination coverages as well. Considering the expected lower vaccination coverage and the smaller number of births, 1,792 births in this cohort, the statistical power will be certainly lower than 80%; yet, coverage of childhood vaccination was still estimated, and associations tests also performed.

2.7 Ethical considerations

This study was approved by the National Ethics Committee in Health Investigation in Guinea-Bissau (Reference number 004/CNES/INASA/2023). For this approval, letters of support of the study were obtained from each region where the study was conducted.

The questionnaires were carried out in a password protected tabled and then stored in an encrypted and password protected computer. Nonetheless, no personal identifiers have been used as participants were only assigned a number and the confidentiality of their answers was assured. Each health center has also an individual attributed 3 or 4-digits code in BHP's data. The signed informed consents are stored in BHP's main office in Bissau. Results of the present research will be disseminated by local stakeholders seeing that the research contributes to the ability to respond to pressing public needs in Guinea Bissau.

3. Results

3.1 Coverage of childhood vaccination

From the 1,792 children born between 1st January 2020 and 1st January 2021, 53 were excluded since data about the health facilities that serve those villages was not available, as these were not part of the 35 health center sample (Fig.4). Completeness of information was obtained for 82% of the sample, yet 6% missing values were found in the variable 'place of birth' and 5% in ANC visits. Maternal socioeconomic level and maternal education level amount to 2% of missing observations each. The other variables, individually, have less than 1% of values missing.

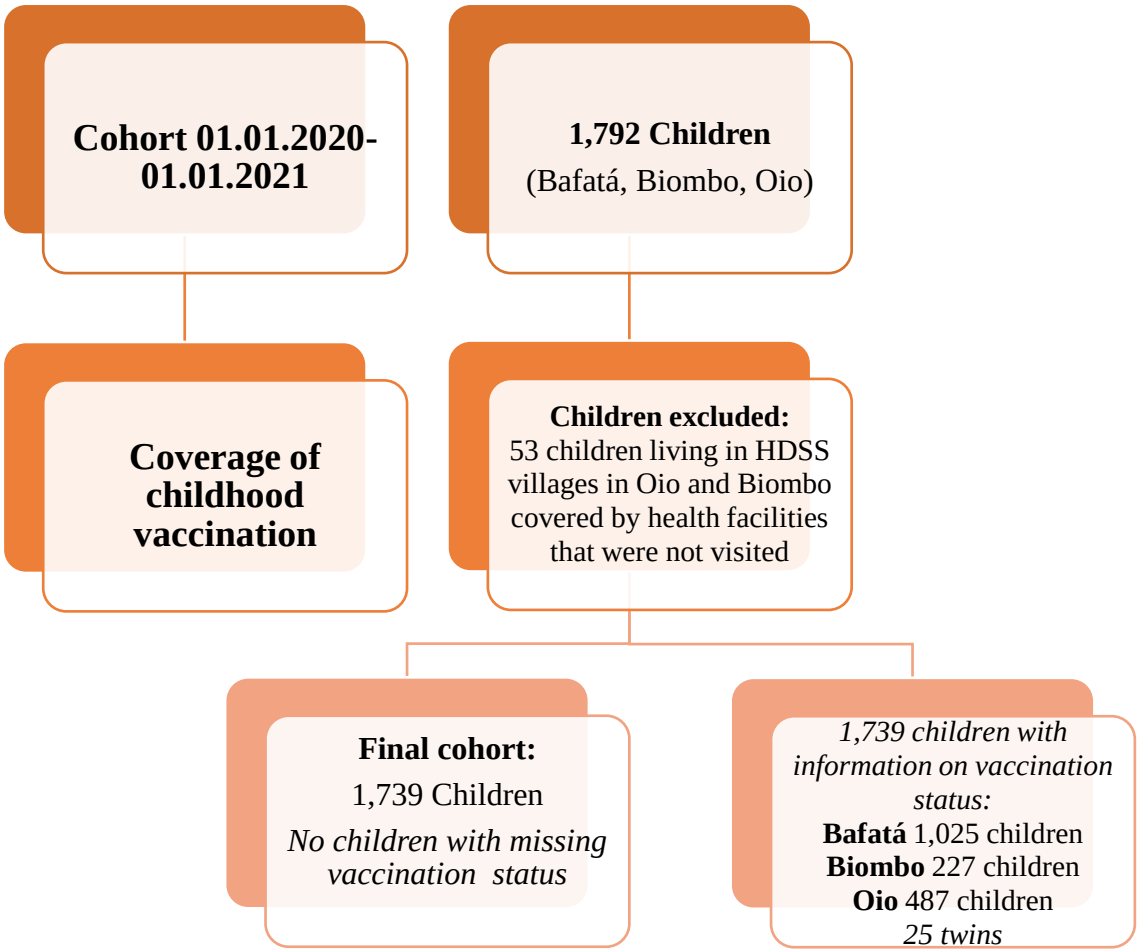

***Fig. 7**. Final cohort for estimation of coverage of childhood vaccination*

Table 5. *Coverage of childhood vaccination: child-maternal socioeconomic, socio-demographic, and obstetric characteristics*

Coverage of childhood vaccination: child-maternal characteristics	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated
Total sample	434 (42)	591 (58)	109 (48)	118 (52)	261 (54)	226 (46)	804 (46)	935 (54)
	1,025 children		227 children		487 children		1,739 children	
Child socio-demographic characteristics								
Sex								
Male	221 (42)	307(58)	52 (48)	57 (52)	127 (51)	121 (49)	400 (50)	485 (52)
Female	213 (43)	283 (57)	57 (48)	61 (52)	134 (56)	105 (44)	404 (50)	449 (48)
Missing	0	1 (100)	0	0	0	0	0	1 (0)
Place of birth								
Health facility	191 (40)	281 (60)	67 (47)	76 (53)	84 (50)	83 (50)	342 (42)	440 (47)
Home	208 (43)	274 (57)	34 (52)	31 (48)	156 (56)	122 (44)	398 (50)	427 (46)
Other	1 (25)	3 (75)	3 (50)	3 (50)	3 (75)	1 (25)	7 (1)	7 (1)
Missing	34 (51)	33 (49)	5 (38)	8 (62)	18 (47)	20 (53)	57 (7)	61 (6)
Birth order								
1st	76 (42)	105 (58)	24 (52)	22 (48)	41 (51)	40 (49)	141 (18)	167 (18)
2nd or 3rd	162 (43)	211 (57)	38 (43)	51 (57)	93 (58)	66 (42)	293 (36)	328 (35)
4th or 5th	108 (42)	146 (58)	22 (47)	25 (53)	65 (49)	68 (51)	195 (24)	239 (26)
> = 6th	88 (42)	122 (58)	24 (56)	19 (44)	60 (55)	50 (45)	172 (21)	191 (20)
Missing	0	7 (100)	1 (50)	1 (50)	2 (50	2 (50)	3 (0)	10 (1)
Maternal socioeconomic, socio-demographic, and obstetric characteristics								
Socioeconomic level								
Level 0-2	21 (43)	28 (57)	27 (55)	22 (45)	50 (52)	47 (49)	98 (13)	97 (10)
Level 3	46 (44)	59 (56)	31 (40)	46 (60)	53 (48)	57 (52)	130 (16)	162 (17)
Level 4	160 (39)	244 (61)	24 (44)	30 (56)	80 (55)	66 (45)	264 (33)	340 (36)
Level 5	185 (43)	243 (57)	12 (43)	16 (579	60 (65)	33 (35)	257 (32)	292 (31)
Missing	22 (57)	17 (44)	15 (79)	4 (21)	18 (44)	23 (56)	55 (7)	44 (5)
Education (years)								
No formal education	248 (42)	342 (58)	27 (54)	23 (46)	137 (52)	129 (49)	412 (51)	494 (53)
>=1 to 4	81 (45)	99 (55)	23 (50)	23 (50)	45 (57)	34 (43)	149 (16)	156 (17)
>=4 to 6	67 (43)	89 (57)	27 (46)	32 (54)	32 (56)	25 (44)	126 (16)	146 (16)
>=6	33 (37)	56 (63)	28 (42)	38 (56)	35 (55)	29 (45)	96 (12)	123 13)
Attended school, class unknown	3 (43)	4 (57)	0	0	3 (75)	1 (25)	6 (1)	5 (1)
Missing	2 (67)	1 (33)	4 (67)	2 (33)	9 (53)	8 (47)	15 (2)	11 (2)
Age (years)								
< 14	2 (67)	1 (33)	0	0	0	0	2 (0)	1 (0)
>=14 to 19	39 (37)	66 (63)	12 (63)	7 (37)	29 (56)	23 (44)	80 (10)	96 (10)
>=19 to 25	161 (43)	211 (57)	30 (45)	37 (55)	93 (57)	71 (43)	284 (35)	319 (34)
>=25 to 35	167 (40)	246 (58)	47 (43)	63 (57)	106 (51)	103 (49)	320 (40)	412 (44)
>=35	60 (50)	61 (50)	17 (63)	10 (37)	31 (60)	21 (40)	108 (13)	92 (10)
Missing	2 (67)	1 (33)	0	0	0	0	2 (0)	1 (0)

Coverage of childhood vaccination: child-maternal characteristics (continuation)	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated
	434 (42)	591 (58)	109 (48)	118 (52)	261 (54)	226 (46)	804 (46)	935 (54)
Total sample	**1,025 children**		**227 children**		**487 children**		**1,739 children**	
Ethnicity								
Fula	302 (43)	408 (57)	1 (100)	0	13 (87)	2 (13)	316 (39)	410 (44)
Mandinga	104 (40)	153 (60)	0	1 (100)	125 (55)	104 (45)	229 (28)	258 (28)
Balanta	14 (45)	17 (55)	9 (39)	14 (61)	115 (51)	111 (49)	138 (17)	142 (15)
Pepel	3 (100)	0	94 (49)	97 (51)	0	0	97 (12)	97 (10)
Manjaco/ Mancanha	2 (50)	2 (50)	5 (50)	5 (50)	1 (20)	4 (80)	8 (1)	11 (1)
Other	4 (33)	8 (67)	1 (100)	1 (100)	7 (64)	4 (36)	11 (1)	13 (1)
Multi-ethnic	0	1 (100)	0	0	0	0	0	1 (0)
Unknow	5 (71)	2 (29)	0	0	0	1 (100)	5 (1)	3 (0)
Mother attended at least one ANC visit								
Yes	389 (41)	551 (59)	99 (48)	107 (52)	229 (54)	193 (46)	717 (89)	851 (91)
No	11 (58)	8 (42)	0	1 (100)	2 (67)	1 (33)	13 (2)	10 (1)
Doesn't know	2 (67)	1 (33)	4 (67)	2 (33)	12 (46)	14 (54)	18 (2)	17 (2)
Missing	32 (51)	31 (49)	6 (43)	8 (57)	18 (50)	18 (50)	56 (7)	57 (6)
Household size								
< 3 children	262 (42)	363 (58)	72 (46)	84 (54)	158 (55)	129 (45)	492 (61)	576 (62)
>=3 to 6 children	143 (41)	204 (59)	29 (48)	32 (52)	80 (49)	82 (51)	252 (31)	318 (34)
>= 6 children	29 (55)	24 (45)	8 (80)	2 (20)	21 (60)	14 (40)	58 (7)	40 (4)
Missing	0	0	0	0	2 (67)	1 (33)	2 (0)	1 (0)

Note: Within the ***total results***, percentages must be read in ***column***; within ***region results***, percentages must be read in ***row***

Table 6. *Coverage of childhood vaccination: village geographical characteristics*

Coverage of childhood vaccination: village geographical characteristics	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated	Not fully vaccinated	Fully vaccinated
Total sample	434 (42)	591 (58)	109 (48)	118 (52)	261 (54)	226 (46)	804 (46)	935 (54)
	1,025 children		**227 children**		**487 children**		**1,739 children**	
Distance to health center (km)								
< 2km	29 (48)	32 (52)	60 (52)	55 (48)	33 (59)	23 (41)	122 (15)	110 (12)
>=2 to 5km	68 (39)	105 (61)	35 (44)	44 (56)	28 (41)	41 (59)	131 (16)	190 (20)
>=5to 8km	76 (35)	144 (65)	6 (38)	10 (63)	73 (58)	53 (42)	155 (20)	207 (22)
>=8km	251 (46)	293 (54)	8 (47)	9 (53)	127 (54)	109 (46)	386 (48)	411 (44)
Missing	10 (37)	17 (63)	0	0	0	0	10 (1)	17 (2)

Note: Within the ***total results***, percentages must be read in ***column***; within ***region results***, percentages must be read in ***row***

i) Child and maternal socioeconomic, socio-demographic, and obstetric characteristics

More than half (54%) of the children born in this cohort is fully vaccinated. Overall, the sample characteristics do not seem to largely differ across vaccination groups (Table 5). Among those who are fully vaccinated, 52% are male, two more percentual points than among those not vaccinated. Being born at a health facility was slightly more common (47%) among fully vaccinated children, compared with 42% among those not vaccinated. Within both fully vaccinated and not fully vaccinated children, first born are the least represented (18%) group between all birth orders.

Mothers categorized in the second highest socioeconomic level (Level 4) are the most represented (36%) between the fully vaccinated children, but also between the not fully vaccinated ones (33%). Yet, most mothers of these cohort's children have no formal education: they constitute more than a half of mothers (53%) among fully vaccinated children and not fully vaccinated children (51%). Mothers between 25 and 35 years of age constitute almost half (44%) of women between fully vaccinated and not fully vaccinated children (40%). Fula children are also the most predominant children among all ethnicities in both groups, with 44% of Fula children among the vaccinated ones and 39% among the not fully vaccinated.

Regarding obstetric characteristics, almost the totality of mothers of both fully vaccinated (91%) and not fully vaccinated (89%) children had at least one ANC visit. Concerning household size, mothers with less than three children represent the largest part of both groups with similar percentages: 62% fully vaccinated children have less than three siblings, and 61% not fully vaccinated children as well.

ii) Village geographical characteristics

Mothers and children tend to live distant from their reference health center, as 44% of fully vaccinated children lived 8km or more from the health center and 48% of not fully vaccinated children lived 8km or more apart from their reference health center as well (Table 6).

iii) Per region child and maternal socioeconomic, socio-demographic, and obstetric characteristics

Biombo children comprise 13% of this cohort with 227 children, followed by Biombo with 487 (28%) children, and by Bafatá with 1,025 (59%). Regarding the vaccination coverage across these three regions, Bafatá is the region where almost two thirds (58%) of children is fully vaccinated while in Oio, more than half (54%) of the children is not. This region, together with Biombo, are below the overall mean of fully vaccinated children from the three regions (54%) (Fig. 8).

Most male and female children are fully vaccinated in the Biombo and Bafatá regions, but not in Oio. Children born in a health facility in Bafatá were predominantly (60%) fully vaccinated and more than a half (56%) of children born at home in Oio were not. The majority of children who were the sixth born child or above, tended to be fully vaccinated in Bafatá (58%), but not in Biombo (44%) or Oio (45%).

Less than 40% (35%) of Oio's children whose mothers are in the highest socioeconomic level (Level 5) were fully vaccinated. More than a half (58%) of Bafatá children whose mothers had no formal education was fully vaccinated (58%) as well as more than 60% (63%) of children whose mothers studied 6 or more years. Younger mothers are a minority in this cohort, however, 63% of Bafatá's children whose mothers were between 14 and 19 years of age is fully vaccinated, while on the contrary, in Biombo only 37% of children with mothers within this age group are. Concerning the ethnicity, it was only in Oio where the majority of children from the respective ethnic groups (except the Manjaco/Mancanha ethnicity) was not fully vaccinated.

Almost 60% (59%) of children of Bafatá's mothers that attended at least one ANC visit, were fully vaccinated, while in Oio, only 46% of children from mothers who attended at least one ANC visit received all the childhood vaccines. Household size seemed to have different vaccination coverages, since children with six or more siblings in the three regions, were, more commonly, not fully vaccinated (80% in Biombo, 60% in Oio and 55% in Bafatá).

iv) Per region village geographical characteristics

Most children from mothers who reside in Bafatá and that live 8km or more from the health center are fully vaccinated (54%), whereas in Oio, 46% of children living 8km or more from the health center, received all the childhood vaccines.

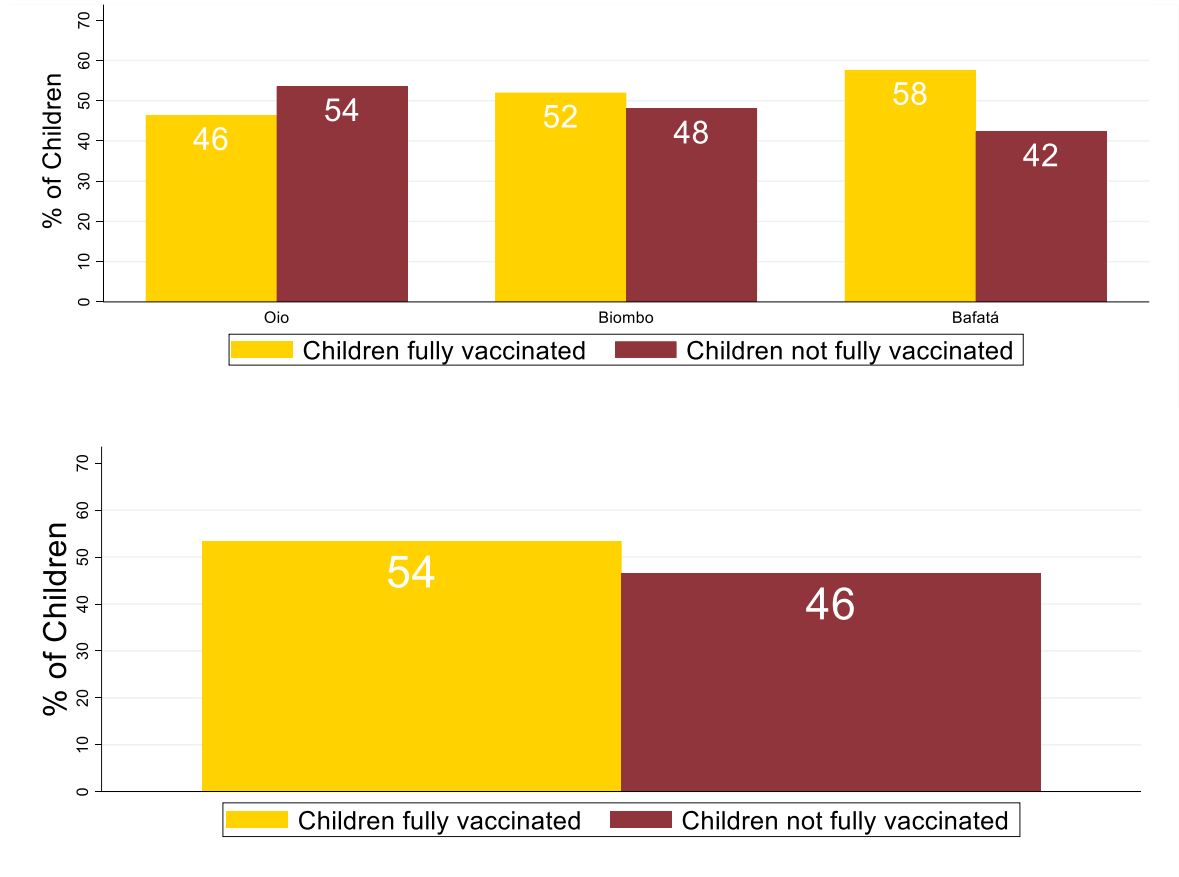

Fig. 8. *Per region and overall coverage of childhood vaccination*

3.2 Coverage of ANC visits

From 4,700 children born between 1st January 2021 and 1st January 2023, 144 were excluded since data about health facilities that serve those villages were not available, as these were not part of the 35 sample of health centres (Fig. 9).

Within this sample with 4,556 children, 42% of mothers attended less than four ANC visits, followed by 31% mothers who attended four or more ANC visits. A fourth of these women a) did recall attending ANC but not the number of consultations or b) did not recall at all, and, in both scenarios, there was no reproductive health card that could allow the verification of the number of ANC visits.

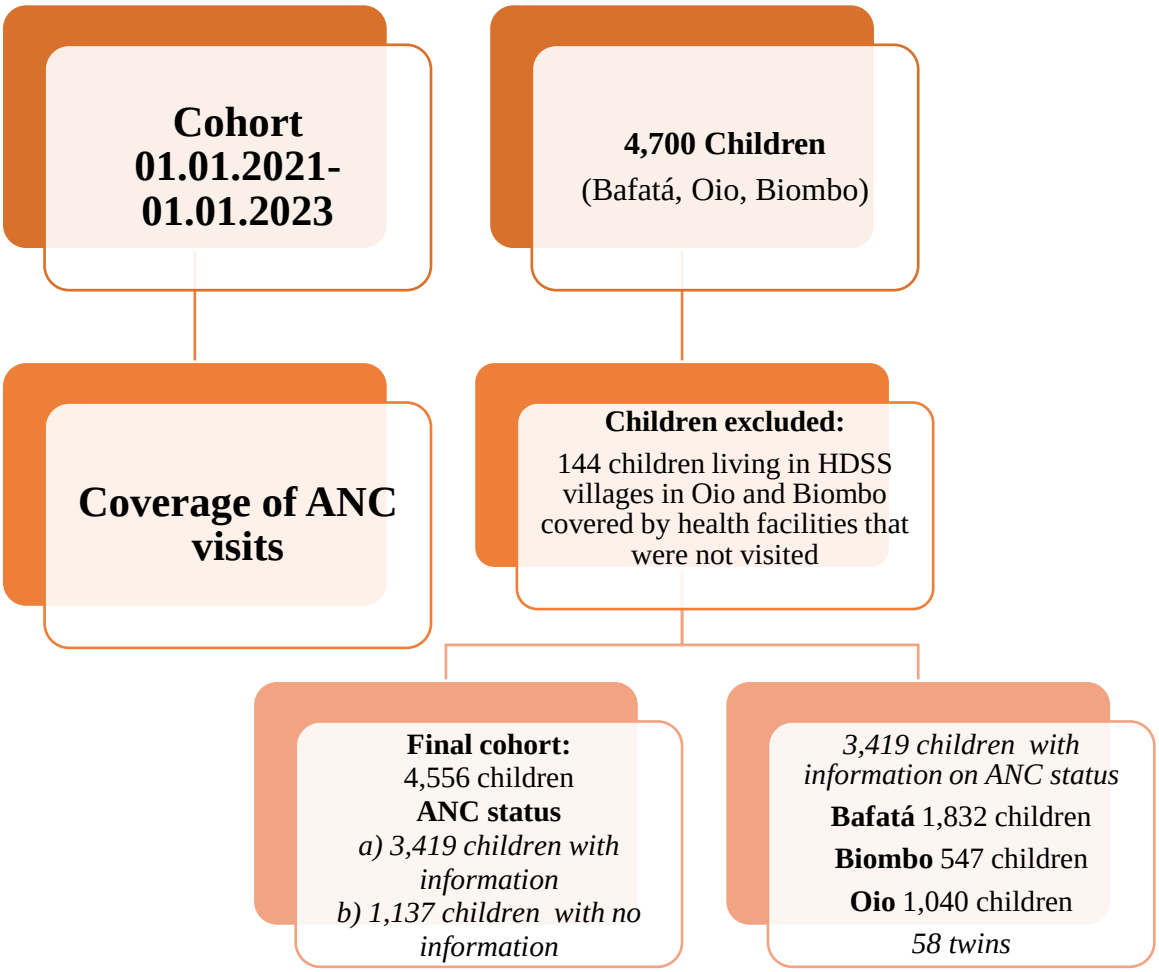

Fig. 9. *Final cohort for estimation of coverage of ANC visits*

Among the 3,419 children who had information on number of ANC visits, 90% of the information is complete and available for analysis, the greater percentage of missing values being derived from the variable socioeconomic level (4%), while the rest of the variables amounts to 1% or less.

i) Child and maternal socioeconomic, socio-demographic, and obstetric characteristics

Considering 3,419 children with information regarding number of ANC visits, we observe that the majority (59%) of children have mothers who attended less than four ANC visits (Table 7).

Among those children from mothers with less than four ANC visits and four or more ANC visits there is no predominant sex. Within those whose mothers had four or more ANC visits or less than four visits, being the second or third child of the mother was more common (34% vs 33%, respectively). Regarding maternal characteristics, it was more predominant for children with four or more ANC visits that their mothers were categorized in the highest socioeconomic level, since 46% of mothers are included in Level 5. However, the same is observed with children whose mothers had less than four ANC visits, as 39% of them, the greater part, belonged to Level 5 of the socioeconomic level as well. Within the children whose mothers had four or more ANC visits, mothers with no formal education are the most represented (44%), with the same group also being more predominant (53%) within children whose mothers had less than four ANC visits. Among children with four or more ANC visits, 44% of mothers were included in the between 25 and 35 years of age group, with this same age group also comprising 42% of women among children with less than four ANC visits. Reiteratively, Fula mothers represent the majority between all ethnic groups and thus, when comparing ethnicities, they comprise the most common ethnicity of children with mothers with more than four ANC visits (43%) but also with less than four ANC visits (34%).

Mothers with known history of stillbirth were a minority, however, 7% of women with a confirmed stillbirth attended four or more ANC visits while pregnant with the cohort's child, with the same percentage of mothers attending less than four ANC visits alike. Children with less than three siblings were predominant in this cohort: 61% of mothers attended four or more ANC visits and 56% less than four ANC visits.

Table 7. *Coverage of ANC visits: child-maternal socioeconomic, socio-demographic, and obstetric characteristics*

Coverage of ANC visits: child-maternal characteristics	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits
Total sample	957 (52)	875 (48)	279 (51)	268 (49)	779 (75)	261 (25)	2,015(59)	1,404(41)
	1,832 children		**547 children**		**1,040 children**		**3,419 children**	
Child socio-demographic characteristics								
Sex								
Male	428 (46)	493 (54)	146 (53)	129 (47)	389 (73)	141 (27)	1,011 (50)	715 (50)
Female	446 (49)	464 (51)	122 (45)	150 (55)	390 (76)	120 (24)	1,004 (50)	688 (49)
Missing	1(100)	0	0	0	0	0	0	1 (0)
Birth order								
1st	116 (43)	156 (57)	60 (48)	66 (52)	134 (66)	69 (34)	310 (15)	291 (21)
2nd or 3rd	315 (51)	307 (49)	110 (56)	87 (44)	234 (75)	79 (25)	659 (33)	473 (34)
4th or 5th	271 (54)	231 (46)	62 (49)	65 (51)	211 (77)	63 (23)	544 (27)	359 (26)
> = 6th	250 (59)	177 (41)	47 (48)	50 (52)	196 (81)	47 (19)	493 (24)	274 (20)
Missing	5 (56)	4 (44)	0	0	4 (57)	3 (43)	9 (0)	7 (1)
Maternal socioeconomic, socio-demographic, and obstetric characteristics								
Socioeconomic level								
Level 0-2	43 (66)	22 (34)	41 (54)	35 (46)	75 (78)	21 (22)	159 (8)	78 (6)
Level 3	90 (63)	53 (37)	87 (55)	72 (45)	148 (76)	48 (24)	325 (16)	173 (12)
Level 4	304 (54)	260 (46)	90 (47)	101 (53)	260 (73)	97 (21)	654 (32)	457 (33)
Level 5	490 (49)	516 (51)	39 (48)	43 (53)	248 (74)	87 (26)	777 (39)	646 (46)
Missing	30 (56)	24 (44)	22 (56)	17 (44)	48 (84)	9 (16)	100 (5)	50 (4)
Education (years)								
No formal education	596 (57)	449 (43)	59 (52)	55 (48)	404 (77)	120 (23)	1,059(53)	624 (44)
>=1 to 4	184 (49)	193 (51)	65 (57)	49 (43)	131 (76)	42 (24)	380 (19)	284 (20)
>=4 to 6	112 (45)	139 (55)	65 (48)	72 (53)	122 (73)	44 (27)	299 (15)	255 (18)
>=6	59 (41)	85 (59	84 (49)	87 (51)	92 (68)	44 (32)	235 (12)	216 (15)
Attended school, class unknown	2 (40)	3 (60)	1 (50)	1 (50)	9 (90)	1 (10)	12 (1)	5 (0)
Missing	6 (40)	9 (60)	6 (55)	5 (45)	21 (68)	10 (32)	30 (1)	20 (1)
Age (years)								
< 14	0	0	1 (33)	2 (67)	1 (100)	0	2 (0)	2 (0)
>=14 to 19	77 (45)	94 (55)	40 (62)	25 (38)	85 (73)	32 (27)	202 (10)	151 (11)
>=19 to 25	340 (55)	277 (45)	88 (55)	73 (45)	261 (73)	96 (27)	689 (34)	445 (32)
>=25 to 35	419 (51)	396 (49)	119 (49)	122 (51)	304 (75)	100 (25)	842 (42)	618 (44)
>=35	115 (55)	96 (46)	29 (41)	42 (59)	117 (79)	31 (21)	261 (13)	169 (12)
Missing	6 (33)	12 (67)	2 (33)	4 (67)	11 (79)	3 (21)	19 (1)	19 (1)

Coverage of ANC visits: child-maternal characteristics (continuation)	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits
Total sample	957 (52)	875 (48)	279 (51)	268 (49)	779 (75)	261 (25)	2,015(59)	1,404(41)
	1,832 children		**547 children**		**1,040 children**		**3,419 children**	
Ethnicity								
Fula	649 (52)	593 (48)	0	1 (100)	26 (67)	13 (33)	675 (34)	607 (43)
Mandinga	272 (53)	241 (47)	0	0	359 (78)	102 (22)	631 (31)	343 (24)
Balanta	19 (56)	15 (44)	37 (71)	15 (29)	359 (73)	132 (27)	415 (21)	162 (12)
Pepel	2 (100)	0	234 (49)	246 (51)	3 (60)	2 (40)	239 (12)	248 (18)
Manjaco/ Mancanha	0	8 (100)	6 (60)	4 (40)	4 (50)	4 (50)	10 (1)	16 (1)
Other	7 (44)	9 (56)	1 (100)	0	26 (76)	8 (24)	34 (2)	17 (1)
Multi-ethnic	2 (100)	0	0	1 (100)	0	0	2 (0)	1 (0)
Unknow	6 (40)	9 (60)	1 (50)	1 (50)	2 (67)	0	9 (0)	11 (1)
Known history of stillbirth								
Yes	73 (52)	67 (48)	17 (41)	24 (59)	42 (81)	10 (19)	132 (7)	101 (7)
No / Primigravidae	882 (52)	807 (48)	261 (52)	244 (48)	736 (75)	250 (25)	1,879 (93)	1,301 (93)
Missing	2 (67)	1 (33)	1 (100)	0	1 (50)	1 (50)	4 (0)	2 (0)
Household size								
< 3 children	504 (49)	519 (51)	191 (53)	167 (47)	439 (73)	164 (27)	1,134 (56)	850 (61)
>=3 to 6 children	380 (55)	311 (45)	73 (45)	90 (55)	283 (78)	78 (22)	736 (37)	479 (34)
>= 6 children	72 (62)	45 (38)	14 (56)	11 (44)	57 (76)	18 (24)	143 (7)	74 (5)
Missing	1 (100)	0	1 (100)	0	0	1 (100)	2 (0)	1 (0)

Note: Within the ***total results***, percentages must be read in ***column***; within ***region results***, percentages must be read in ***row***

ii) Village geographical characteristics

Regarding distance, from the children whose mothers had less than four ANC visits prior their birth, almost the half (47%) of them lived 8km or more from their health centers. Differently, from those whose mothers completed four or more ANC visits, 41% lived 8km or more from their health centers (Table 8).

Table 8. *Coverage of ANC visits: village geographical characteristics*

Coverage of ANC visits: Village geographical characteristics	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits	< 4 ANC visits	>=4 ANC visits
Total sample	957 (52)	875 (48)	279 (51)	268 (49)	779 (75)	261 (25)	2,015(59)	1,404(41)
	1,832 children		**547 children**		**1,040 children**		**3,419 children**	
Distance to health center (km)								
< 2km	34 (33)	69 (67)	134 (49)	138 (51)	76 (72)	28 (28)	244 (12)	235 (17)
>=2 to 5km	149 (52)	139 (48)	105 (55)	86 (45)	92 (80)	23 (20)	346 (17)	248 (18)
>=5to 8km	158 (45)	194 (55)	33 (54)	28 (46)	253 (72)	97 (28)	444 (22)	319 (23)
>=8km	591 (57)	452 (43)	7 (30)	16 (70)	358 (76)	113 (24)	956 (47)	581 (41)
Missing	25 (54)	21 (46)	0	0	0	0	25 (1)	21 (1)

Note: Within the ***total results***, percentages must be read in ***column***; within ***region results***, percentages must be read in ***row***

iii) Per region child and maternal socioeconomic, socio-demographic, and obstetric characteristics

Bafatá is the region that has most of this cohort's births, 1,832 births (53%), trailed by Oio with 1,040 births (30%) and Biombo with 547 births (17%). From all regions, children residing in Biombo and Bafatá were the ones whose most mothers attended four or more ANC visits (49% vs 48%, respectively). Contrastingly, in the Oio region, 75% of all women attended less than four ANC visits.

Most mothers of female (76%) and male (73%) children born in Oio had predominantly less than four ANC visits during their pregnancy, contrary to Bafatá female (51%) and male (49%) children whose mothers predominantly attended four or more ANC visits. Regarding birth order, 81% of Oio's children who are the sixth child and above, had less than four ANC visits.

Reiteratively, it is within the Oio region that the starkest differences can be seen in terms of maternal characteristics: almost 80% (78%) of children whose mothers were categorized in the lowest socioeconomic levels (Level 0 to 2) had less than four ANC visits, with this difference also being observed with Biombo children, whose 54% of mothers categorized in the lowest levels also attended less than four ANC visits. More than a half (77%) of children

from mothers who did not attend formal education and who lived in Oio had less than four ANC visits, this also being verified in Bafatá (57%) and Biombo (52%). In terms of mothers' age group, in Oio, 79% of children whose mothers were 35 years and above, had less than four ANC visits yet, in Biombo, 59% of mothers in the same age group had four or more ANC visits. Children from mothers belonging to the Mandinga ethnic group and residing in Oio, more frequently had less than four ANC visits than four or more ANC visits (78% vs 22%, respectively), a stark difference. However, in the three regions, the majority of all ethnic groups' mothers attended less than four ANC visits.

Most (81%) children in Oio whose mothers had a previous stillbirth had less than four ANC visits, while more than a half (59%) of Biombo's mothers with a previous stillbirth attended four or more ANC visits while pregnant with the cohort's child. When it comes to household size, it was only in Biombo, within the children that have between three to six siblings, where the greater part (55%) of their mothers had four or more ANC visits.

iv) *Per region village geographical characteristics*

Residing 8km or more from the reference health center was experienced by 57% of Bafatá's children whose mothers attended less than four ANC visits, with this distance being more evident in Oio, where only 24% of mothers who reside that far away completed four or more ANC visits.

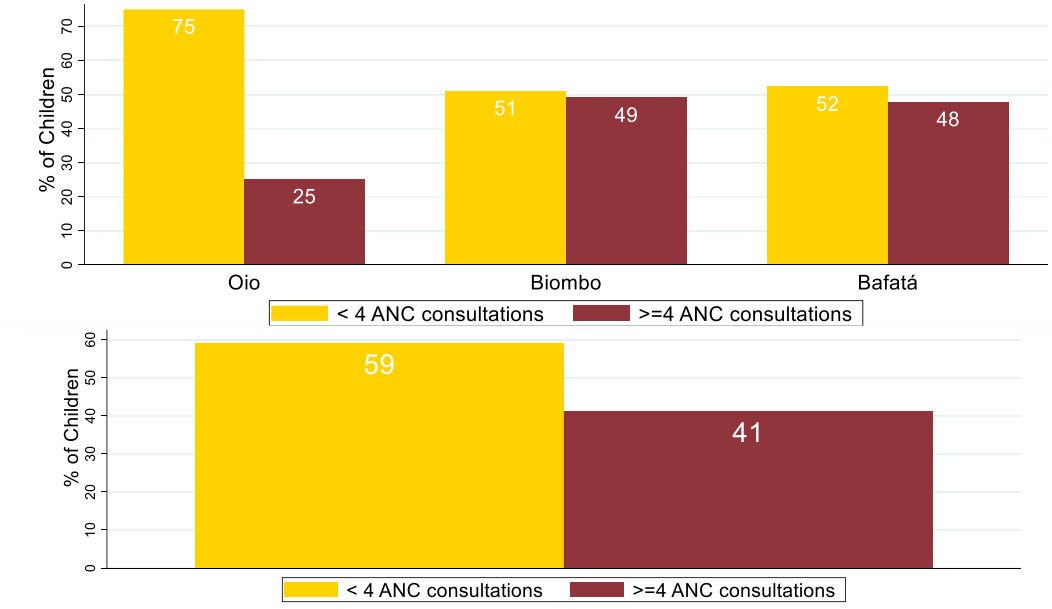

Fig. 10. *Per region and overall coverage of ANC visits*

3.3 Coverage of facility birth

As facility birth was studied using the same baseline cohort as the one used for coverage of ANC visits, from 4,700 children, 144 were excluded as well, due to children being covered by health facilities that were not visited. From these, 853 more children had to be removed derived from the organization of MCHS, as in the regions of Bafatá and Oio, some women must deliver at the hospital independently of having a health center assigned, where childhood vaccination and ANC services are provided (sub-chapter 2.2.2).

Within this sample, 21 children have no information on place of birth. Thus, the available cohort includes 3,682 children (Fig. 11). Among these children, 90% of the information is complete and available for analysis, the greater percentage of missing values being derived from the variable socioeconomic level (4%), while the rest of variables amount to 1% or less.

i) Child and maternal socioeconomic, socio-demographic, and obstetric characteristics

Slightly over than a half (52%) of children were not born at a health facility (home/other), (Table 9). Overall, the sample characteristics do not seem to greatly differ across the place of birth of the two groups.

There is no sex difference to mention among the children born in a health facility or not. Since children born during the dry season are more represented in this cohort, they constitute the majority (57%) of children born in a health facility and outside a health facility (63%). Among children both born in a health facility and not born in a health facility, being the second or third born was more common, with 32% of births occurring in a hospital/ health center and 36% at home/other.

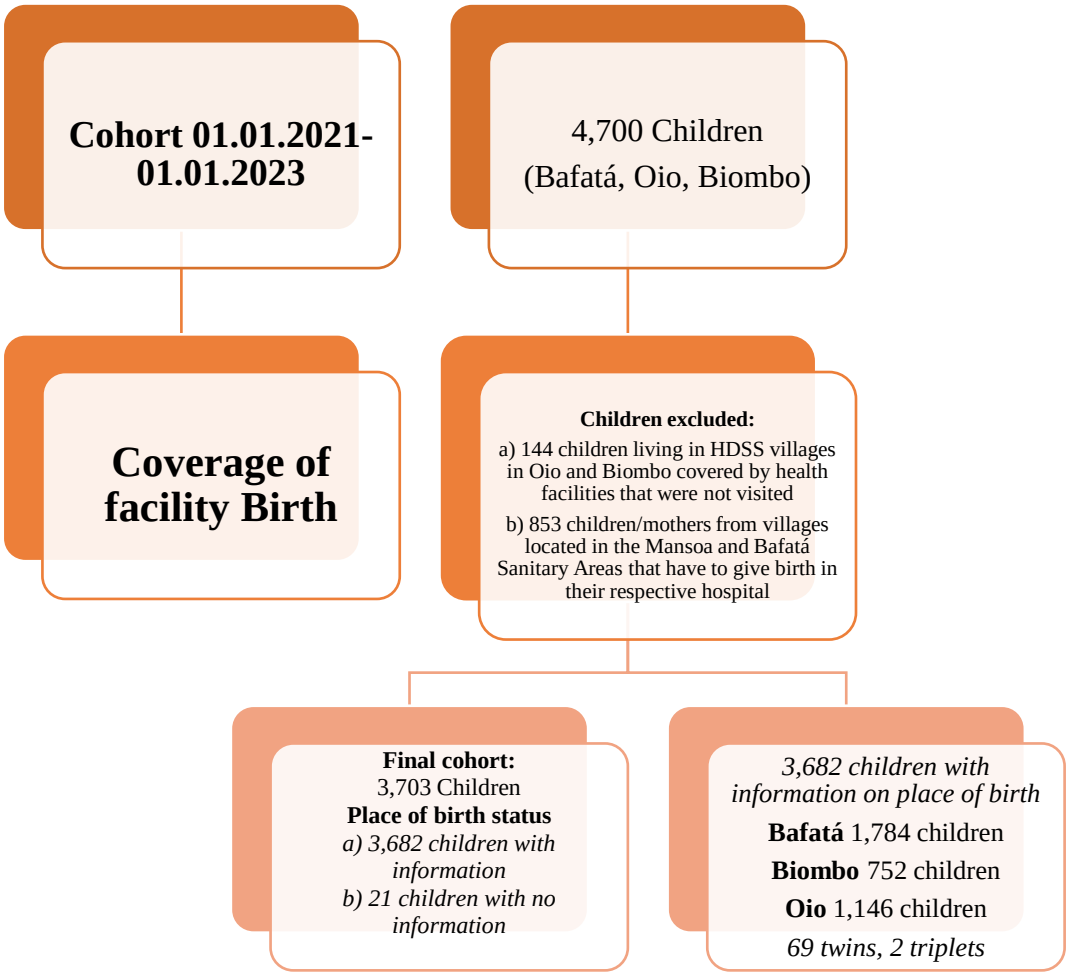

Fig. 11. *Final cohort for estimation of coverage of facility birth*

Within facility-born children, children whose mothers were from the lowest socioeconomic levels (Level 0 to 2) are the least represented ones (8%), and only 1 percentual point differ these children not born in a health facility, among children with mothers from Level 0 to 2. Women with no formal education were predominant in this cohort: children from mothers that never attended formal education are the most represented among facility births (44%) and non-facility births (53%). Among children born in a health facility, women aged between 25 and 35 years constitute 40% of mothers, and almost half (44%) of the mothers who did not deliver their children at a health facility. Similarly to the other outcomes, the Fula ethnic group is the one highlighted both among facility-born children, with 37% of births, and among children born outside the health facility, with 36% births of Fula children.

Table 9. *Coverage of facility birth: child-maternal socioeconomic, socio-demographic, and obstetric characteristics*

Coverage of facility birth: child-maternal characteristics	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	No facility birth	Facility birth	No facility birth	Facility birth	No facility birth	Facility birth	No facility birth	Facility birth
Total sample	904 (51)	880 (49)	254 (34)	498 (66)	750 (65)	396 (35)	1,908 (52)	1,774 48)
	1,784 children		**752 children**		**1,146 children**		**3,682 children**	
Child socio-demographic characteristics								
Sex								
Male	431 (49)	445 (51)	135 (35)	249 (65)	383 (65)	202 (35)	949 (50)	896 (51)
Female	471 (52)	434 (48)	119 (33)	247 (67)	366 (65)	194 (35)	956 (50)	875 (49)
Missing	2 (67)	1 (33)	0	2 (100)	1 (100)	0	3 (0)	3 (0)
Season of the year								
Dry season	565 (53)	500 (47)	143 (35)	260 (65)	491 (66)	249 (34)	1,199 (63)	1,009(57)
Rainy season	339 (47)	380 (53)	111 (32)	238 (68)	259 (64)	147 (36)	709 (37)	765 (43)
Birth order								
1st	70 (26)	203 (74)	31 (17)	151 (83)	102 (47)	117 (53)	203 (11)	471 (27)
2^{nd} or 3^{rd}	332 (54)	283 (46)	97 (35)	177 (65)	249 (71)	103 (29)	678 (36)	563 (32)
4^{th} or 5^{th}	278 (60)	187 (40)	66 (41)	95 (59)	218 (71)	90 (29)	562 (29)	372 (21)
> = 6^{th}	223 (52)	203 (48)	59 (44)	75 (56)	177 (69)	81 (31)	459 (24)	359 (20)
Missing	1 (20)	4 (80)	1 (100)	0	4 (44)	5 (56)	6 (0)	9 (1)
Maternal socioeconomic, socio-demographic, and obstetric characteristics								
Socioeconomic level								
Level 0-2	46 (60)	31 (40)	40 (36)	71 (64)	85 (70)	36 (30)	171 (9)	138 (8)
Level 3	85 (57)	65 (43)	88 (41)	127 (59)	161 (68)	77 (32)	334 (18)	269 (15)
Level 4	283 (52)	262 (48)	77 (29)	185 (71)	254 (67)	124 (33)	614 (32)	571 (32)
Level 5	456 (48)	500 (52)	33 (29)	79 (71)	205 (60)	139 (40)	694 (36)	718 (40)
Missing	34 (61)	22 (39)	16 (31)	36 (69)	45 (69)	20 (31)	95 (5)	78 (4)
Education (years)								
No formal education	551 (53)	492 (47)	62 (42)	86 (58)	406 (67)	199 (33)	1,019 (53)	777 (44)
>=1 to 4	184 (52)	173 (48)	56 (36)	100 (64)	126 (65)	67 (35)	366 (19)	340 (19)
>=4 to 6	122 (47)	140 (53)	66 (34)	130 (66)	100 (59)	69 (41)	288 (15)	339 (19)
>=6	34 (32)	72 (68)	66 (28)	174 (73)	90 (65)	49 (35)	190 (10)	295 (17)
Attended school, class unknown	4 (80)	1 (20)	1 (50)	1 (50)	8 (80)	2 (20)	13 (1)	4 (0)
Missing	9 (82)	2 (18)	3 (30)	7 (70)	20 (67)	10 (33)	32 (2)	19 (1)
Age (years)								
< 14	0	0	1 (33)	2 (67)	0	0	2 (0)	2 (0)
>=14 to 19	64 (35)	119 (65)	23 (24)	72 (76)	78 (54)	66 (46)	165 (9)	257 (14)
>=19 to 25	309 (52)	290 (48)	77 (32)	160 (68)	245 (65)	132 (35)	631 (33)	582 (33)
>=25 to 35	419 (54)	362 (46)	108 (35)	201 (65)	305 (68)	145 (32)	832 (44)	708 (40)
>=35	103 (51)	99 (45)	42 (42)	58 (58)	109 (70)	47 (30)	254 (13)	204 (12)
Missing	9 (47)	10 (53)	3 (38)	5 (63)	12 (67)	6 (33)	24 (1)	21 (1)

Coverage of facility birth: child-maternal characteristics (continuation)	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	No facility birth	Facility birth	No facility birth	Facility birth	No facility birth	Facility birth	No facility birth	Facility birth
Total sample	904 (51)	880 (49)	254 (34)	498 (66)	750 (65)	396 (35)	1,908 (52)	1,774 (48)
	1,784 children		**752 children**		**1,146 children**		**3,682 children**	
Ethnicity								
Fula	658 (51)	630 (49)	0	1 (100)	20 (45)	24 (55)	678 (36)	655 (37)
Mandinga	213 (52)	198 (48)	0	0	320 (60)	210 (40)	533 (28)	408 (23)
Balanta	24 (48)	26 (52)	41(55)	34 (45)	392 (73)	142 (27)	457 (24)	202 (11)
Pepel	0	0	211 (32)	450 (68)	1 (33)	2 (67)	212 (11)	452 (25)
Manjaco/ Mancanha	2 (25)	6 (75)	0	10 (100)	3 (100)	0	5 (0)	16 (1)
Other	4 (26)	13 (76)	1 (100)	0	10 (36)	18 (64)	15 (1)	31 (2)
Multi-ethnic	1 (100)	0	0	1 (100)	0	0	1 (0)	1 (0)
Unknow	2 (22)	7 (78)	1 (33)	2 (67)	3 (100)	0	6 (0)	9 (1)
Mother attended at least one ANC visit								
Yes	883 (50)	868 (50)	237 (34)	460 (66)	658 (65)	358 (35)	1,778 (93)	1,686(95)
No	9 (64)	5 (36)	6 (75)	2 (25)	45 (74)	16 (26)	60 (3)	23 (1)
Doesn't know	3 (50)	3 (50)	10 (27)	27 (73)	40 (69)	18 (31)	53 (3)	48 (3)
Missing	9 (69)	4 (31)	1 (10)	9 (90)	7 (64)	4 (36)	17 (1)	17 (1)
Mother has a pregnancy card at first visit after birth								
Yes	750 (52)	697 (48)	192 (36)	342 (64)	624 (65)	334 (35)	1,566 (82)	1,373(77)
No	59 (48)	65 (52)	4 (33)	0	50 (75)	17 (25)	109 (6)	82 (5)
Doesn't know	4 (40)	6 (60)	0	8 (67)	44 (64)	25 (36)	52 (3)	39 (2)
Missing	91 (45)	112 (55)	58 (28)	148 (72)	32 (62)	20 (38)	181 (9)	280 (16)
Known history of stillbirth								
Yes	70 (52)	65 (48)	14 (30)	38 (79)	40 (62)	25 (38)	124 (7)	128 (7)
No/ Primigravidae	834 (51)	813 (49)	239 (34)	460 (66)	709 (66)	370 (34)	1,782 (93)	1,643(93)
Missing	0	2 (100)	1 (100)	0)	1 (100)	0	2 (0)	2 (0)
Known history of facility delivery								
Yes	291 (43)	379 (57)	105 (34)	207 (67)	174 (57)	132 (43)	570 (30)	718 (40)
No/ Primigravidae	132 (43)	172 (57)	46 (25)	137 (75)	186 (64)	104 (36)	364 (19)	413 (23)
Unknow	481 (59)	329 (41)	103 (40)	154 (60)	390 (71)	160 (29)	974 (51)	643 (36)
Household size								
< 3 children	477 (47)	537 (53)	155 (30)	355 (70)	421 (62)	262 (38)	1,053 (55)	1,154(65)
>=3 to 6 children	365 (57)	280 (43)	80 (40)	122 (60)	281 (73)	106 (27)	726 (38)	508 (29)
>= 6 children	62 (50)	62 (50)	18 (46)	21 (54)	47 (63)	28 (37)	127 (7)	111 (6)
Missing	0	1 (100)	1 (100)	0	1 (100)	0	2 (0)	1 (0)

Note: Within the ***total results***, percentages must be read in ***column***; within ***region results***, percentages must be read in ***row***

Table 10. *Coverage of facility birth: village geographical characteristics*

Coverage of facility birth: Village geographical characteristics	Region							
	Bafatá		Biombo		Oio		Total	
	Frequency(%)		Frequency(%)		Frequency(%)		Frequency(%)	
	No facility birth	Facility birth	No facility birth	Facility birth	No facility birth	Facility birth	No facility birth	Facility birth
Total sample	904 (51)	880 (49)	254 (34)	498 (66)	750 (65)	396 (35)	1,908 (52)	1,774 48)
	1,784 children		**752 children**		**1,146 children**		**3,682 children**	
Distance to health center (km)								
< 2km	16 (19)	67 (81)	111 (29)	268 (71)	47 (35)	88 (65)	174 (9)	423 (24)
>=2 to 5km	134 (44)	168 (56)	102 (40)	155 (60)	94 (67)	46 (33)	330 (17)	369 (21)
>=5to 8km	210 (48)	226 (52)	37 (40)	55 (60)	344 (69)	156 (31)	591 (31)	436 (25)
>=8km	523 (58)	381 (42)	4 (17)	20 (83)	265 (71)	106 (30)	804 (42)	524 (30)

Note: Within the ***total results***, percentages must be read in ***column***; within ***region results***, percentages must be read in ***row***

Concerning the obstetric characteristics, almost the totality of mothers who both delivered in a health facility (95%) and that did not deliver in a health facility (93%), attended at least one ANC visit. Similarly, more of those children who were born at a health facility (77%) and outside a health facility (82%) had mothers that possessed a pregnancy card at first visit after birth. Children with confirmed older stillborn siblings were uncommon, however, 7% of children born at a health facility and not born a health facility had an older stillborn sibling. Almost half (40%) of children whose older siblings were known to be born at a health facility, were also born at a health center/hospital, while among the half (51%) of children not born in a health facility, it is unknown if their older siblings were born in a health facility or not. Within the children who were born at a health facility, 65% had less than three siblings, while having less than three siblings was less frequent (55%) among children not born at a health facility.

ii) Village geographical characteristics

Within the facility-born children, 30% of their mothers, the most represented, lived 8km or more from the health center, compared with 42% of children not born in a health facility (Table 10).

iii) Per region child and maternal socioeconomic, socio-demographic, obstetric characteristics

Biombo contributes to this cohort with 752 births (21%), Oio with 1,146 (31%), and Bafatá with 1,784 (48%) births. More than a half (66%) of Biombo's children was born at a health facility, whereas in Oio, more than two-thirds (65%) of children were delivered outside a health facility. In Bafatá, place of birth is equally divided between health facility and at home/other. Biombo was the region where facility-births were 18 % above the mean of the three regions (Fig. 12).

The female sex stands out in Biombo, as almost 70% (67%) of female children was born at a health facility, and both sexes are highlighted in Oio, as 65% of female and male children were born at home/other. Also in Biombo, close to 70% (68%) of children born during the rainy season was born at a health facility and in Oio, most (66%) children born during the dry season were delivered at home/other. First born children in Bafatá (74%) and Oio (53%) were more predominantly born at a health facility.

Exploring maternal characteristics, 70% of Oio's women categorized in the lowest socioeconomic levels (Level 0 to 2), delivered their child at home/other, whereas 64% of Biombo's mothers in the same socioeconomic levels delivered in a health facility. Biombo's residing children whose mothers went to school 6 years or more, were predominantly (73%) delivered at a health facility, the same observed with 68% of Bafatá's children whose mothers attended formal education 6 years or more. In Biombo, 76% mothers aged between 14 and 19 years delivered at a health facility, whereas 54% of Oio's children with mothers in that age group were not born in a health facility. Within mothers' ethnicity per region, in Biombo, children of Pepel mothers were mostly (68%) born in a health facility, while more than 70% (73%) of Balanta women, in Oio, delivered outside a health facility.

Concerning obstetric categories, Biombo and Oio were the regions with the largest differences between facility or non-facility-birth. In the first region, 66% of women that attended at least one ANC visit tended to deliver the cohort child at a health facility, whereas in Oio, only 35% women who attended at least one ANC visit were delivered in health facility. Across all regions, the greater part of mothers had a pregnancy card at first visit after

birth, though in Oio more than half (65%) of mothers possessing a card delivered at home/other. Biombo's children whose at least one of the older siblings was a stillborn, were predominantly (79%) born at a health facility. Having older siblings know to being born at a health facility, is linked to more than 50% of facility births in Bafatá (57%) and Biombo (67%), but not in Oio (43%). In Biombo, a child with six siblings or more was more frequently (54%) delivered at a health facility yet, in Oio, a child with these characteristics was more commonly born at home/other (63%).

iv) Per region village geographical characteristics

The majority (81%) of children from Bafatá women who live less than 2km away were born at a health facility, as well as the majority (71%) of Biombo's and Oio's children (65%).

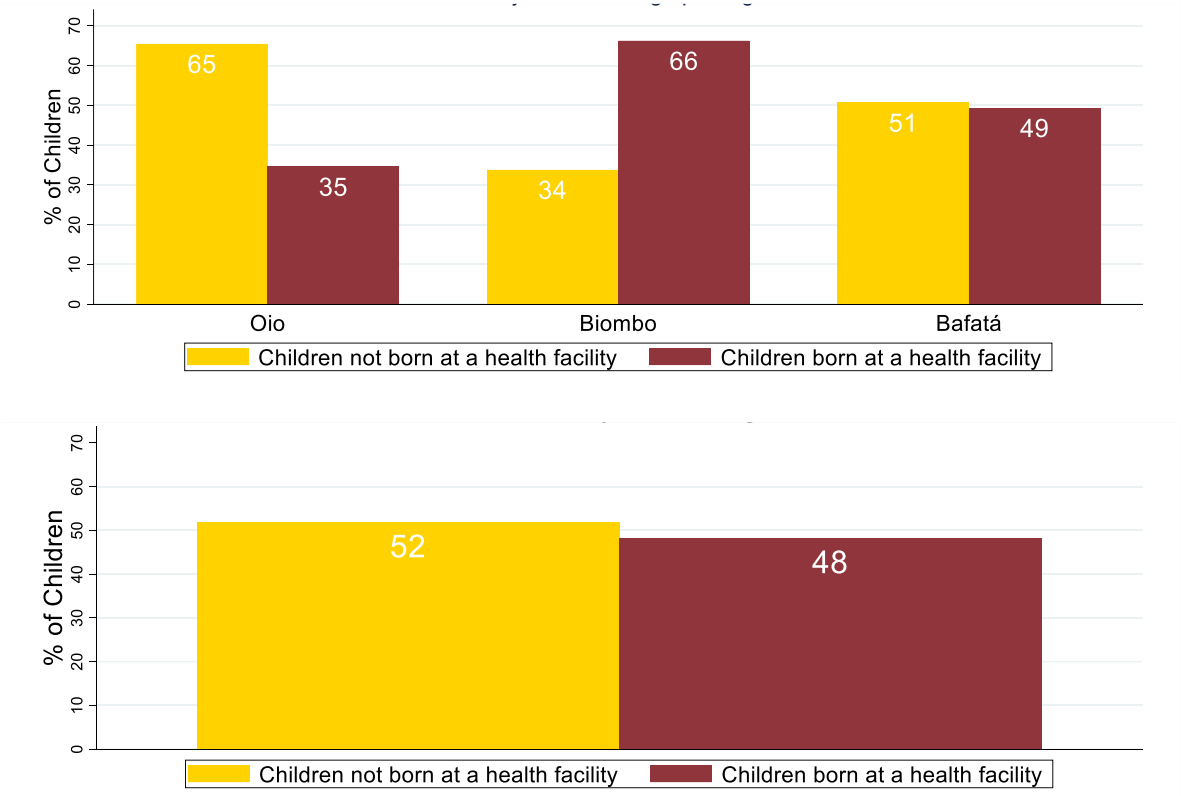

Fig. 12. *Per region and overall coverage of facility birth*

3.4 Health center and health professionals' socio-demographic and job-related characteristics

3.4.1 Health centers' characteristics

In total, there are 14 health centers in Bafatá, 20 in Oio and seven in Biombo, amounting to 41 health centers in the three regions (this is excluding hospitals, private clinics or religious health facilities, outside the scope of this research). We prioritized data collection at health centers that cover HDSS villages (29 health centers) and added six more health centers that worked in collaboration with BHP in other projects, though not covering HDSS villages. As such, all the health centers in Biombo (seven) and Bafatá (14) and 14 health centers in Oio were seen. The characteristics collected at the six health centers that do not have HDSS's villages (four in Oio and two in Bafatá) complement the description of the health region. However, they were excluded from the statistical analysis. Details of the health centers are provided in Table 11. There is no missing information to report.

i) Overall health centers' characteristics

Thirty-five health centers were visited. Most (89%, *n*=31) of health centers were type C, with no type A health centers interviewed. All but two health centers were usually open during the 7 days of the week, providing around-the-clock emergency care from Monday to Sunday, 24 hours a day. The two remaining health centers, located nearby a regional hospital working all days of the week, were accessible only during weekdays. In this context, these health centers do not provide emergency care, being open approximately 8 hours/day from Monday to Friday.

Table 11. *Health centers' characteristics of the 35 health centers visited*

Health center characteristics	Region			
	Bafatá*	Biombo**	Oio***	Total
Total sample	Frequency *(%)*	Frequency *(%)*	Frequency *(%)*	Frequency *(%)*
	14 (40)	**7 (20)**	**14 (40)**	**35 (100)**
Type of health center				
B	2 (15)	1 (14)	1 (7)	4 (11)
C	12 (85)	6 (86)	13 (93)	31 (89)
Emergency care (nº of days/week)				
0	1 (7)	0	1 (7)	2 (6)
7	13 (93)	7 (100)	13 (93)	33 (94)
ANC consultations (nº of days/week)				
5	12 (86)	6 (86)	13 (93)	31 (89)
7	2 (14)	1 (14)	1 (7)	4 (11)
Children vaccination (nº of days/week)				
5	11 (79)	7 (100)	12 (86)	30 (86)
7	3 (21)	0	2 (14)	5 (14)
Waiting time for ANC consultations (hours)				
< 2	7 (50)	2 (29)	8 (57)	17 (49)
>= 2	7 (50)	5 (71)	6 (43)	18 (51)
Waiting time for children vaccination (hours)				
< 2	10 (71)	1 (14)	10 (71)	21 (60)
>=2	4 (28)	6 (86)	4 (28)	14 (40)
Waiting time for women in labour (hours)	0	0	0	0
ANC consultations costs XOF (EUR)	0	0	0	0
Reproductive health card cost XOF (EUR)				
0	9 (64)	5 (72)	12 (86)	26 (74)
500 (0.76)	0	1 (14)	1 (7)	2 (6)
1000 (1.52)	4 (29)	0	1 (7)	5 (14)
Unfixed /unknown	1 (7)	1 (14)	0	2 (6)
Tetanus card cost XOF (EUR)				
0	14 (100)	6 (86)	13 (93)	33 (94)
500 (0.76)	0	1 (14)	1 (7)	2 (6)
Children's vaccines cost	0	0	0	0
Infant health card cost (XOF/EUR)				
0	10 (71)	3 (43)	13 (93)	26 (74)
500 (0.76)	0	2 (29)	1 (7)	3 (9)
1000 (1.52)	3 (21)	1 (14)	0	4 (11)
Unfixed /unknown	1 (8)	1 (14)	0	2 (6)
Delivery assistance cost (XOF/EUR)	0	0	0	0

Health center characteristics (continuation)	Region			
	Bafatá*	Biombo**	Oio***	Total
Total sample	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
	14 (40)	**7 (20)**	**14 (40)**	**35 (100)**
Emergency evacuation vehicles				
No	11 (79)	1 (14)	9 (64)	21 (60)
Yes	3 (21)	6 (86)	5 (36)	14 (40)
Type of emergency vehicles				
Ambulance	3 (100)	5 (83)	2 (40)	10 (71)
Motorcycle	0	1 (17)	3 (60)	4 (29)
Cost of evacuation transportation XOF (EUR)	0	0	0	0
Health center performs ultrasound				
No	13 (93)	6 (86)	14 (100)	33 (94)
Yes	1 (7)	1 (14)	0	2 (6)
Pre/post-partum room exclusive for women				
No	4 (31)	0	2 (15)	6 (18)
Yes	9 (69)	7 (100)	11 (85)	27 (82)
Quality of infrastructure (by health responsible)				
Reasonable	9 (64)	3 (43)	6 (43)	18 (51)
Good	4 (29)	3 (43)	8 (57)	15 (43)
Very good	1 (7)	1 (14)	0	2 (6)

Notes: * **Bafatá**: Women of fertile age:70,454; Pregnant women:14,411; Children from 0-11 months:11,103 ****Biombo:** Women of fertile age:23,992; Pregnant women:4,907; Children from 0-11 months:3,781*****Oio:** Women of fertile age:46,313; Pregnant women:9,473; Children from 0-11 months:7,299

In the case of ANC consultations, four health centers regularly provided this type of consultations 7 days per week, with almost 90% (89%, *n*=31) of the health centers usually carrying out ANC consultations 5 days per week, from Monday to Friday.

The scenario is similar with children's vaccination: the majority (86%, *n*=30) of the health centers generally performed it 5 days per week, from Monday to Friday, with a few (14%, *n*=5) vaccinating children 7 days per week. In both types of MCHS, in all health facilities, the starting time of these services routinely was between 8-9.30am. The closing time, officially, was 4pm, yet all the 35 health centers responsibles reported usually only closing when the last woman or child were attended to.

The health center's responsible person was also asked to provide an estimate of the waiting times for ANC visits or for childhood vaccination in the week prior to the interview. Reportedly, waiting times for ANC visits, ranged from 30min to 4 hours and women had to wait 2 hours or more to be attended by a health professional in half (51%, *n*=18) of health centers. The situation is different with the waiting times for childhood vaccination: in two-thirds (60%, *n*=21) of the health centers, reportedly, women had to wait less than 2 hours to get their children vaccinated. To add that the waiting time for this MCHS ranged between 10min to 5 hours. Concerning the waiting times for a woman in labor, in all health centers, the responsibles reported that women were immediate attended upon arrival.

Regarding direct costs of ANC consultations, all health centers' responsible persons did not report any usual obligatory fees for women seeking ANC, meaning that this service was free-of-charge. This statement was applied to both women that come from the Sanity Area of the health center or for women from other Sanitary Areas (therefore within the range from other health centers). However, when it comes to the reproductive health card (a card where the obstetric history and the current pregnancy evolution is registered) given to women in their first ANC visit, it has, in turn, a fee in some health facilities. This fee is reportedly applied when the Direção Regional de Saúde does not provide the health centers with the reproductive health cards and thus, the facilities are required to pay for copies, and, in turn, some health facilities "sell" them to the women. During the period when the questionnaires were collected, there were reported regional shortages of reproductive health cards.

At the time of the questionnaires, in 74% (*n*=26) of the health centers, this card was indeed gratuitous, yet in the others, this cost ranged from 500 XOF (0.76 EUR) in two health centers, reaching a maximum of 1,000 XOF (1.52 EUR) in five health centers. Two health centers had either unfixed or unknown costs, although both charged for reproductive health cards when they did not have originals and needed to produce them locally. The single health center in Bafatá that mentioned unfixed costs, charged women depending on their perceived socioeconomic status, always charging either 500 XOF (0.76 EUR) or 1,000 XOF (1.52 EUR), depending on the health worker's judgement of the woman ability to pay. In the second health center charging unknown costs, in Biombo, health professionals explained that

due to the regional shortage of the cards, the woman herself had to pay to copy the card elsewhere and thus, there is no information of the cost.

Also during the ANC visits that women receive during pregnancy, usually a tetanus vaccine is administered. While the vaccine itself has, reportedly, no cost, the tetanus card, where the number of doses and the administration dates are registered, had a cost of 500 XOF (0.76 EUR) in two health centers, at the time of interview. Again, these two health centers charged the same price for both women from that Sanitary Area and from others Sanitary Area (and consequently covered by other health center). Yet, the seven health centers that were charging either 500 (0.76 EUR) or 1,000 XOF (1.52 EUR) for the reproductive health card, did not charge for the tetanus card.

Children's vaccination is another MCHS offered by the Bissau-Guinean health centers. Comparable to the ANC service, it was reported by all health centers' responsible people that all the routine vaccines for children usually are free of charge, being for children that belong to the health center's Sanitary Area, or that come from other Sanitary Area (and thus, within the range of another health center) or that are born at home. The infant health card (given at the moment in which the child receives the first vaccine from the routine vaccination's scheme, and where all the vaccines administered and the dates are registered in), nevertheless, assumed certain fees in some health centers. This time, these fees were applied in two scenarios: if health centers must copy them due to shortage of distribution, then some health centers demand women to pay a fee; in another instances, a "fine" for card access was applied if the woman gave birth at home and took the child to the health center for the first vaccine. Some of these health centers charged women in both situations: either as a "fine" for delivering at home and as consequence of the infant card shortages. At the time where the questionnaires were conducted, there was a regional shortage of this type of cards.

In 74% (*n*=26) of the health centers, the children's card undoubtedly had no reported usual cost. However, here we can note how frequent the "fines" are applied to a woman who delivered at home and afterward brought the child for the first vaccine. The fees described on the Table 11 are applicable to all children, independently of where they live or if they were born at home or at a health facility. From the seven health centers regularly applying a fee for obtaining the infant card, two of them charged payment exclusively as a "fine" if the

woman gave birth at home. This "fine" was in the order of 500 XOF (0.76 EUR) in one health center, or 1,000 XOF (1.52 EUR) in the other. The other five health centers, when charging a fee for the card, would either demand a payment both because a) they only had copies of the card that they would then "sell" to the women and b) as a "fine" for home birth (both fees at the exact same price). Like the reproductive health card, when a card fee was in fact charged, the highest fee of 1,000 XOF (1.52 EUR) was the most frequent amount demanded. The same two health facilities, one in Biombo and the other in Bafatá, that charged for the reproductive health card, charged for the infant health card: one health center charging an unfixed cost, the other one charging an unknown cost. Concerning the other MCHS of assistance during child delivery at a health facility, all health centers reported no usual fees.

In case of emergencies where evacuation to the regional/national hospital is needed, it was inquired if the health centers owned a vehicle for patients' transportation. Two-thirds (60%, *n*=21) of the health centers had no vehicle for evacuation. Of the ones that did have means of transporting children/women, 71% (*n*=10) had an ambulance as a vehicle and 29% (*n*=4) only had motorcycles. To add that all health centers did not refer to any transportation fees for women or under-5 children that need to be evacuated in emergency cases. Among the 14 health centers with an available vehicle, in four facilities, one of the health professionals on shift must leave the health center to drive the evacuation vehicle.

Performing ultrasounds during the women's pregnancy is extremely uncommon during normal pregnancies in Guinea-Bissau, especially outside the capital. In fact, from the 35 health centers, only two performed ultrasounds during ANC (or if suspicion of stillbirth or other delivery-related complications arise), but in one health center it was under payment of a fee.

Proceeding to the infrastructure of the health centers, 33 health centers had a room designated for women in labor or for recovery after labor. The remaining two health centers lacking in this description, are the health centers that only provide ANC and vaccination for women and children, as regional hospitals exist in their vicinities (and where expectant mothers go to give birth). However, these rooms were not always exclusively for women's use: in 18% (*n*=6) of health centers, health professionals must, occasionally, join women in labor or recovery with other male patients (this was reported to happen mostly during rainy season,

with the increase of malaria cases). When it comes to the quality of the health centers' infrastructure, no health center's responsible evaluated it as "very bad" or "bad". Half (51%, *n*=18) evaluated their health center's infrastructure as reasonable and 6% (*n*=2) even evaluated it as "very good".

The next variables described, to ease interpretation, are presented in Figures (Fig.13-16). All but one health center reported distributing free-of-charge medicine to women and children, and the majority distributed mosquito nets to expecting mothers (74%, *n*=26) and children (71%, *n*=25) (in the remaining health centers there was a regional shortage of mosquito nets). Sixty percent (*n*=21) of health centers responding distributing "other" type of incentives, were referring to infants' cereals (either in case of severe malnutrition or prevention of malnutrition), food for impoverished women or post-partum kits (allegedly also distributed by PIMI a few years ago to improve coverage of facility births, not existent anymore) (Fig. 13).

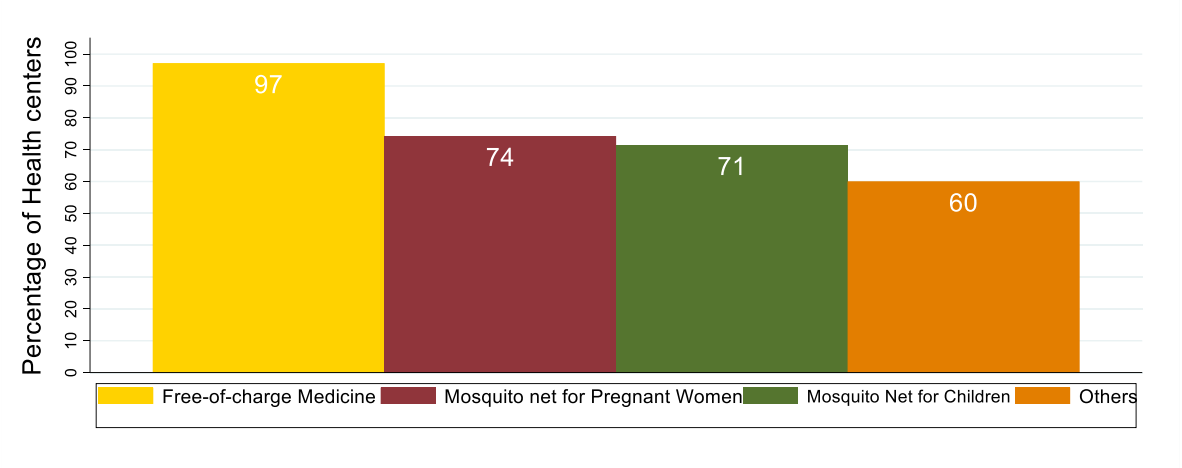

Fig. 13. *Reported material support/ incentives distributed at the health centers*

In terms of gratuitous complementary diagnostic exams provided by health centers, HIV, urin, hemoglobin, syphilis and blood glucose tests are regularly provided at the health centers. Pregnacy tests are actually available in 19 health centers that constitute this sample, however only in five are they free-of-charge (Fig.14).

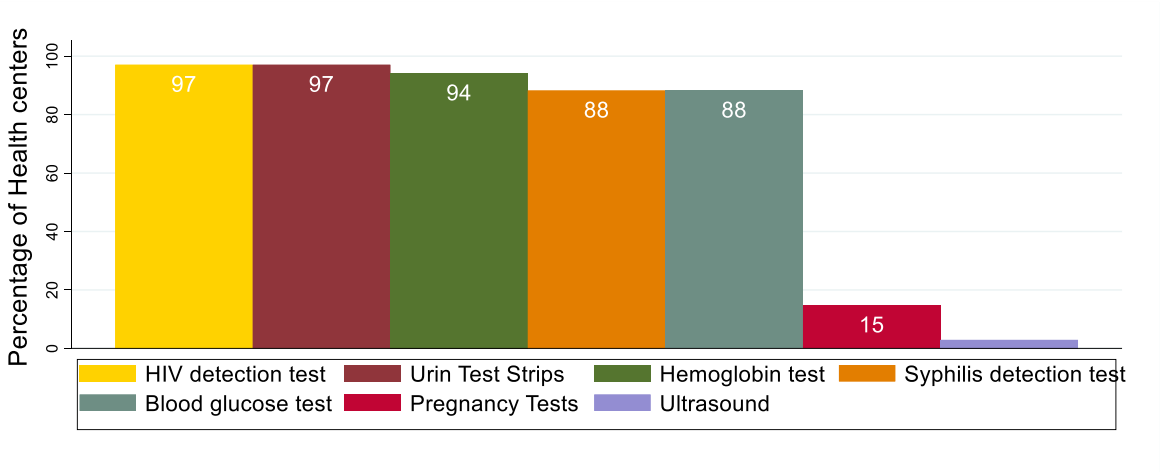

Fig. 14. *Reported free-of-charge, complementary diagnostic exams provided by health centers*

From a pre-existent list of essential medicines, the health center's responsible person was also asked to point out essential free-of-charge medicines that were out-of-stock. More than a half (54%, *n*=19) of health centers had one type or more of anthelmintics out-of-stock, and almost a half (49%, *n*=17) at least one group of analgesics missing. At least one group of contraception medicine, essential to planned parenthood, was reportedly missing from 43% (*n*=15) of the total health centers. Antimalarial drugs and antiretrovirals (one or more type of drug) were missing in 14% (*n*=5) of health centers (Fig.15).

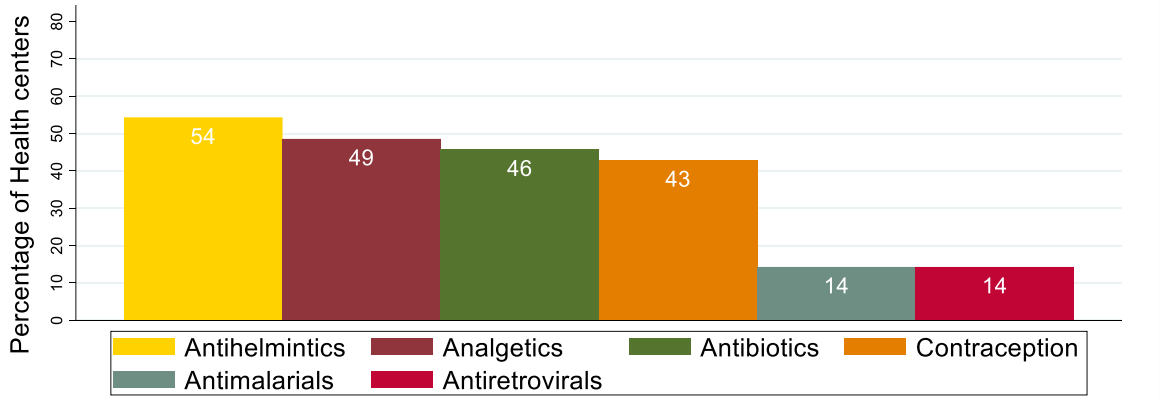

Fig. 15*. Reported essential out-of-stock and free-of-charge medicine (at least one type of medicine per group of essential medicines)*

Health centers' responsible persons were also showed a list of pre-categorized essential working instruments and inquired which of them did they miss or considered insufficient in the health center. From the measuring devices, the greater part (54%, *n*=19) of health centers missed or had insufficient blood pressure monitors. Relating to infrastructure, 31% (*n*=11) of health centers had either no water or a precarious source of (clean) water and 23% (*n*=8) no electricity or a precarious source of electricity (Fig. 16 a)). Delivery instruments were very frequently insufficient or non-existent in almost 70% (69%, *n*=24) of health centers and serological tests were classified as insufficient or missing in 46% (*n*=16) of health centers (Fig. 16 b)). Moreover, 49% (*n*=17) of health centers, half of them, disclosed not having (or not having enough) emergency equipment (e.g., infant and/or maternal mask for resuscitation, aspirator).

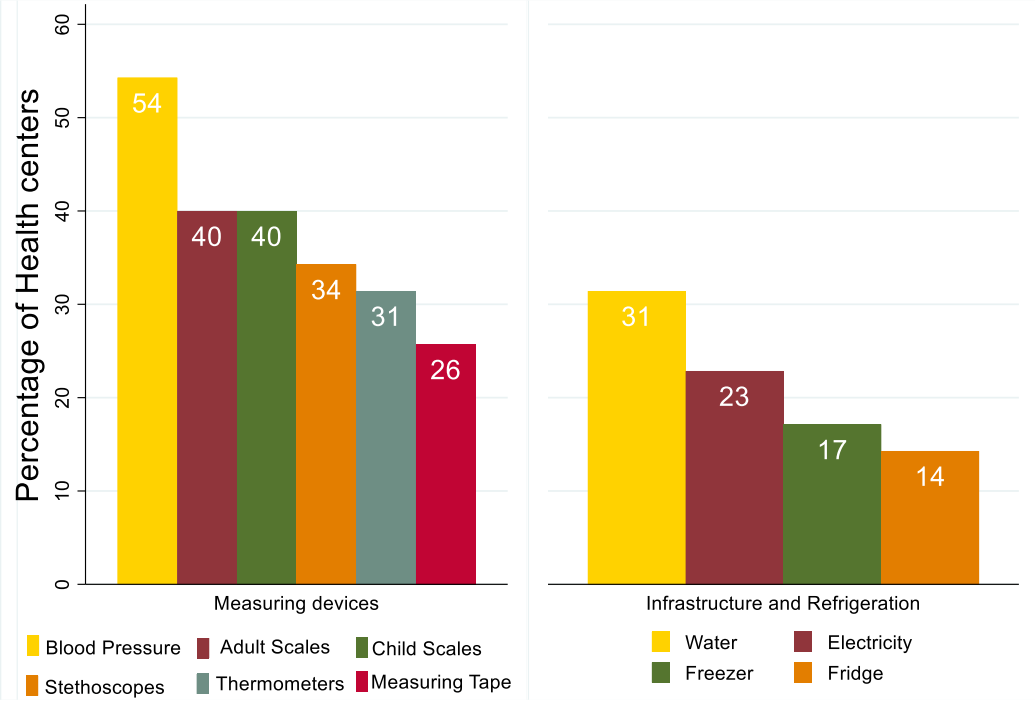

Fig. 16 a). *Reported working instruments missing or considered insufficient (measuring devices, infrastructure, and refrigeration)*

As previously mentioned, more than half (54%, *n*=19) of the visited health centers mentioned out-of-stock infant health cards and a half (49%, *n*=17) out-of-stock reproductive health cards (Fig.16 b)).

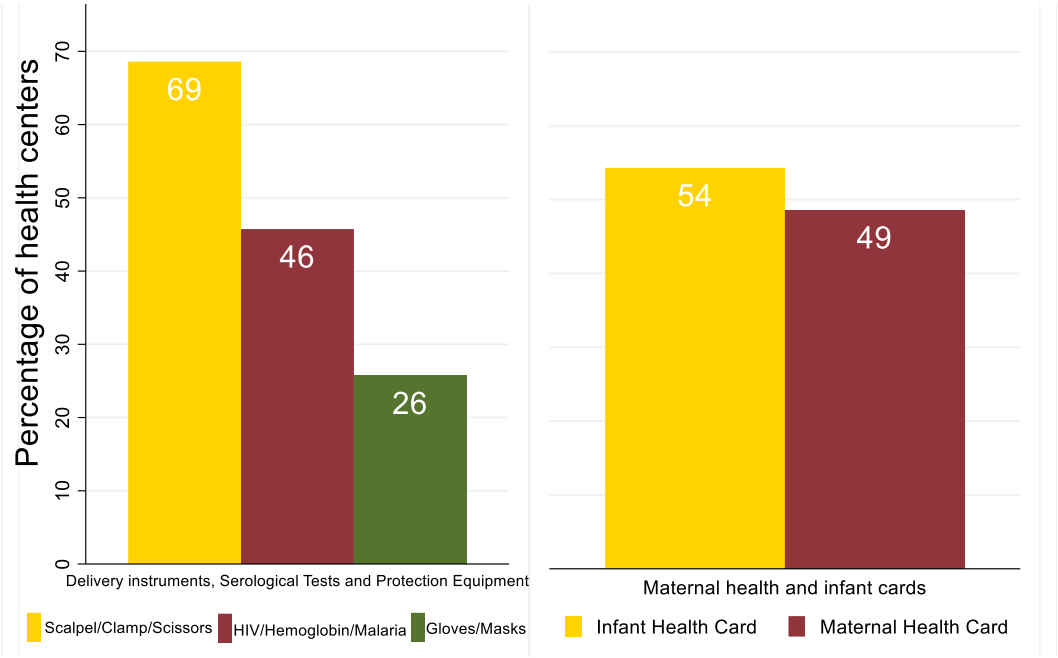

Fig. 16 b). *Reported working instruments missing or considered insufficient (delivery instruments/serological tests/protection equipment and maternal and infant health cards)*

ii) Per region health center's characteristics

Bafatá is distinctively the region with the highest number of women of fertile age, pregnant women and children from 0-11 months covered by the health centers, trailed by Oio and Biombo (133) (Table 11). At the same time, Bafatá is also the health region that includes the health centers with more resources (e.g., more type B health centers, more health centers offering childhood vaccination and ANC consultations for 7 days per week instead of 5 days per week, where the tetanus card is never charged, and more emergency vehicles are available). Despite this fact, this is also the region where fees and "fines" for the reproductive health and infant card are most frequently charged.

From a total of four type B health centers visited, the Bafatá region holds two of them, whereas Biombo and Oio hold one type B health center each one (all the type B health centers existing in the regions were visited). Most (93%, *n*=13) of health centers in Bafatá and Oio were usually open 7 days per week for emergencies. The other two health centers, one in each region, that do not provide emergency care, are the aforementioned supported by regional hospitals.

Regarding the regularity of the MCHS, there were two health centers in Bafatá that provided ANC consultations 7 days per week, one in Biombo and one in Oio as well. Only health centers in Oio and Bafatá offered childhood vaccination during the same period, two in the first region and three in the second. Both services across all regions were more common to be offered from Monday to Friday.

Pertaining to waiting times for these services, in half (50%, *n*=7) of the health centers in Bafatá, women, in the week prior to the questionnaire, encountered waiting times for ANC consultations at the health centers of 2 hours or more. Waiting for 2 hours or more, was reported in the majority (71%, *n*=5) of Biombo health centers. On the other hand, in the greater part (57%, *n*=8) of Oio's health centers, women had to wait, in the week before, less than 2 hours. When it comes to waiting times to get their children vaccinated, women in Biombo, in the week prior to the interview, had to wait 2 hours or more in the majority (86%, *n*=6) of the region's health centers. Contrarily, in 71% (*n*=10) of health centers located in Bafatá and Oio, women waited less than 2 hours.

Regarding possible health centers fees for the use of MCHS, it was specified previously that no health center in the three regions disclosed any usual type of costs for ANC visits. Yet, in four Bafatá's health centers, the reproductive health card, at the time of the interview, had a cost of 1,000 XOF (1.52 EUR), and one health center, although charging an unfixed cost, always charged in case of lack of cards. Bafatá was not only the region where most of the health centers charged a fee during that period, but also the region that charged the most the highest fee of 1,000 XOF (1.52 EUR). The tetanus card, however, was only not free-of-charge in one health center in Biombo and in one in Oio.

Returning to the childhood vaccination costs, none mentioned a usual payment for a routine vaccine, but the infant health card that was not always gratuitous. Seventy-one percent (*n*=10) of Bafatá's health centers and 93% (*n*=13) of Oio's did not charge any price in any situation. However, more than half (57%, *n*=4) of Biombo's health centers charged a fixed fee of either 500 XOF (0.76 EUR) or 1,000 XOF (1.52 EUR), and one health center an unknow fee (as the woman herself had to copy the card). In fact, the three other facilities demanding the highest price of 1,000 XOF (1.52 EUR) were in Bafatá.

When it comes to having an emergency vehicle for evacuation, only three health centers from the Bafatá region had vehicles, and all of them were ambulances. Biombo, in turn, had six emergency vehicles, five of them ambulances, while Oio had had five vehicles, three of them ambulances.

Ultrasound was only available in one health center in Bafatá (free-of-cost as well) and one health center in Biombo (this one charging a fee). Concerning the availability of a room exclusive for women during pre/post-partum, 31% (*n*=4) of Bafatá's health centers and 15% (*n*=2) in the Oio region, mentioned having to join women in recovery/in labor with male patients on some occasions. Still on the health centers' infrastructure, regarding their quality, 64% (*n*=9) of health centers' responsible persons in Bafatá, the majority, evaluated their health center as "reasonable"; in Biombo, the responsibles were divided between two classifications, "reasonable" and "good" (43%, *n*=3, each one); in Oio, the majority (57%, *n*=8) of health centers were evaluated by the responsibles as "good".

3.4.2 Health professionals' socio-demographic and job-related characteristics

The health professionals' socio-demographic characteristics were also collected. Two sets of socio-demographic characteristics were obtained and divided in ***Part a)*** and ***Part b)***. ***Part a)*** describes 240 health professionals that are employed in all the health centers *(see Supplementary Information 4 for the respective table)* and ***Part b)*** describes the 88 health workers with whom the structured interviews were conducted (Table 12). There is no refusal of participation from the health professionals to report.

i) Overall health professionals' socio-demographic and job-related characteristics

Part a) *All 240 health professionals employed at the 35 health centers*

In Biombo, Oio and Bafatá, the median of health professionals per health center was of 10 [Interquartile Range (IQR): 5-15], with the total of 240 health workers in the three regions. Unsurprisingly, nurses, by far, belonged to the health professional cadre with greater representation in the total of the health centers (63%), followed by 18% of midwifes, 8% of laboratory and pharmacy technicians, and 5% of physicians. Other health workers' cadres amounted to less than 7%, but include interns, activists and non-official administrative help.

From the 53 health workers that were absent in the last seven planned shifts, only 9% (*n*=5) had "striking" has a justification for non-attendance. The other workers were absent due to medical or other reasons.

A clear overrepresentation of women is noticeable, with 59% female health workers in the three regions. To add that, in the nurses' group, the health cadre most frequent in the total of health centers, the distribution of males and females is quite balanced, with 53% female nurses and 47% male nurses. On the other hand, all 43 midwifes were females and almost all (83%) physicians were males.

The years of working experience of the health workers ranged from less than 1 year to 51 years. Half (49%) of the health professionals from the three regions had less than 5 years of experience, and 9% were working for the Bissau-Guinean health system for 20 years or more.

Comparable to what is observed in the population census, the Balanta ethnicity comprised most (19%) of the health workers' sample, tailed by the Pepel ethnic group with 15% of health professionals, by the Fula with 13%, and by the Manjaco with 11% of healthcare workers. Other ethnicities and multi-ethnic health professionals comprised less than 30%.

Part b) *88 health professionals with whom the structured interviews were conducted*

The interviews conducted with 88 health professionals available at time of visit [IQR 3: 2-3, health professionals interviewed per health center] attempted to explore some possible predictors of quality of MCHS in the studied regions. More than two thirds (64%) of the respondents were female, had a median of 4 [IQR 4: 2-9.5] years of working experience in the Guinean health system and 19% were Fula, followed by 18% of Pepel, 17% Manjaco, and 13% Mancanha, among others. Almost 80% (74%) were nurses, followed by 16% of midwives (Table 12). There is no refusal of participation to report.

Table 13 shows the answers obtained in the structured interviews. In face of the former question about the quality of the health center's infrastructure, their responses seem to contrast not only with the ones from the health center responsibles, but also represent both extremes of the scale. One "very bad" classification was this time obtained, and simultaneously 17 health professionals answered as their health center having a "very good"

infrastructure. Nevertheless, the "reasonable" classification was still the most predominant, comprising 54% of the answers.

Table 12. *Characteristics of the health professionals interviewed*

Characteristics of the health professionals interviewed	Region			
	Bafatá	Biombo	Oio	Total
Total sample	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
	34 (39)	**20 (23)**	**34 (39)**	**88 (100)**
Sex				
Male	13 (38)	5 (25)	14 (41)	32 (36)
Female	21 (62)	15 (75)	20 (59)	56 (64)
Years on service (years, IQR)	4 (2-5)	7.5 (5-12)	4 (2-10)	4 (2-9.5)
Ethnicity				
Balanta	7 (21)	2 (10)	8 (24)	17 (19)
Pepel	3 (9)	6 (30)	7 (21)	16 (18)
Mancanha	6 (18)	3 (15)	2 (6)	11 (13)
Fula	4 (12)	1 (5)	4 (12)	9 (10)
Manjaco	6 (18)	5 (25)	4 (12)	15 (17)
Mandinga	1 (3)	0	3 (9)	4 (5)
Bijagós	2 (6)	0	0	2 (2)
Beafada	1 (3)	0	2 (6)	3 (3)
Felupe	9 (3)	0	0	1 (1)
Multi-ethnic	2 (6)	3 (15)	3 (9)	7 (8)
Others	2 (6)	0	1 (3)	3 (3)
Cadre				
Nurse	18 (53)	16 (80)	31 (91)	65 (74)
Midwife	11 (32)	1 (5)	2 (6)	14 (16)
Physician	3 (9)	0	0	3 (3)
Laboratory technician/ Pharmacy technician	0	2 (10)	2 (0)	4 (5)
Others	0	1 (5)	0	1 (1)

Two-thirds (60%) of the health workers reported "always" having explained, in the prior month, the procedures being done to the child (vaccination) or to the woman (ANC consultation, delivery assistance), and 25% claimed explaining "almost always". "Never" describing the procedures to the patient was not at any time chosen.

To the question of how frequently the health professional was discontent with his/her work at the health center in the prior month, 40% responded "never" being discontent, followed

by 37% of health workers that responded “sometimes” being discontent in the month prior. Three health professionals claimed “always” having felt discontent in the month before the interview. From those health professionals answering that they felt discontent “sometimes”, “almost always” and “always” in the month before, more than a half (61%) reported that they did not show their discontentment, 15% that they would reprimand the patient, explaining what they did wrong/what they should to instead, 10% said that they became irritated, impatient or screamed at the patient, 7% mentioned their dissatisfaction only being visible in their face (altered facial expression), 2% affirmed not coming to work, and only one health professional explained that he/she charged for an otherwise free service.

To explore the existence of a possible friction when the health professional’s ethnicity was not coincident with the one from the mother/child, it was asked whether they felt difficulties caring for women or children from a different ethnicity than theirs. The answers appear to be somewhat balanced with 52% workers answering “no” and the other part (48%) responding affirmatively. The participants that answered that they felt difficulties, were then asked the type of difficulties that they faced. A half (53%) of the participants explained that their difficulties were attributed to communication issues, either because the patients spoke a language that the health professional did not speak, or because the woman was cognitively struggling to understand what was being said. The other part, 33% of health professionals, associated their difficulties with the acceptance of the patient’s health behaviors that stemmed from their religious and cultural beliefs. Lastly, six health professionals answered a combination of the other two categories. Related with the communication’s difficulty expressed by the participants, health workers were asked how they normally proceed when caring for a woman that did not speak a language that they could understand. All respondents indicated that they would either request someone that spoke the same language (e.g., other professional, family member, CHW) to translate for them, and/or use sign language with the woman.

i) Per region health professionals’ socio-demographic and job-related characteristics

More health professionals in Bafatá, compared with the other two regions, were dissatisfied with their work and expressed difficulties providing for women or children from a different ethnicity.

Table 13. *Results from the structured interviews*

Structured interviews	Region			
	Bafatá*	**Biombo****	**Oio*****	**Total**
Total sample	**Frequency *(%)***	**Frequency *(%)***	**Frequency *(%)***	**Frequency *(%)***
	34 (39)	**20 (23)**	**34 (39)**	**88 (100)**
IQR 3 (2-3)				
Quality of infrastructure (by health workers)▲				
Very bad	0	0	1 (4)	1 (1)
Reasonable	13 (45)	16 (73)	12(48)	41 (54)
Good	8 (28)	1 (5)	8 (32)	17 (22)
Very good	8 (28)	5 (23)	4 (16)	17 (22)
Job related characteristics				
Frequency of the procedure's explanation				
Rarely	0	0	1 (3)	1 (1)
Sometimes	5 (15)	4 (17)	3 (10)	12 (14)
Almost always	7 (21)	8 (35)	7 (23)	22 (25)
Always	22 (64)	11 (48)	20 (64)	53 (60)
Dissatisfaction with the work				
Never	11 (32)	8 (36)	16 (51)	35 (40)
Rarely	3 (9)	5 (22)	3 (10)	11 (13)
Sometimes	17 (50)	7 (30)	9 (29)	33 (37)
Almost always	2 (6)	1 (4)	2 (7)	5 (6)
Always	1 (3)	1 (4)	1 (3)	3 (3)
Doesn't know	0	1 (4)	0	1 (1)
Demonstration of the dissatisfaction ♠				
Doesn't show his/her dissatisfaction	11 (55)	8 (89)	6 (50)	25 (61)
Reprimands the patient	6 (30)	0	0	6 (15)
Becomes irritated, impatient or screams at the patient	1 (5)	1 (11)	2 (17)	4 (10)
Altered facial expression	1 (5)	0	2 (17)	3 (7)
Misses work	1 (5)	0	1 (8)	2 (5)
Charges for the free service	0	0	1 (8)	1 (2)
Difficulties providing for women/children of different ethnicity				
No	10 (29)	18 (78)	18 (58)	46 (52)
Yes	24 (71)	5 (22)	13 (42)	42 (48)
Type of difficulty experienced┼				
Communication (different language/woman struggling to understand)	12 (50)	2 (40)	8 (62)	22 (53)
Acceptance of women's health behaviors (religion/culture)	7 (29)	2 (40)	5 (38)	14 (33)
Both communication and health behaviors	5 (21)	1 (20)	0	6 (14)

Notes: * **Bafatá**: Women of fertile age:70,454; Pregnant women:14,411; Children from 0-11 months:11,103 ****Biombo:** Women of fertile age:23,992; Pregnant women:4,907; Children from 0-11 months:3,781*** **Oio:** Women of fertile age:46,313; Pregnant women:9,473; Children from 0-11 months:7,299 ▲In order to obtain at the very least 2 structured interviews per health center, 12 health center's responsibles answered both the questionnaire as well the structured interviews. Since this question is repeated in both inquiries**, 12 answers were then dropped only in this variable**, leaving **76 answers**. The other questions, expect when highlighted, resume to having **88 answers.** ♠ Type of difficulty experienced is only answered by health professionals who answered affirmatively to "Difficulties providing for women/children of different ethnicity".
┼ Demonstration of dissatisfaction is only answered by health professionals who answered Sometimes, Almost Always or Always to "Dissatisfaction with the work".

Regarding the quality of infrastructure as viewed by health workers and per region, some opposing views were obtained. In more detail, one health center from the Oio region for instance, received concurrently a "good" classification from the health responsible, but a "very bad" and "reasonable" grading from two other health professionals employed there.

More than half (64%) of Bafatá's health professionals reported to have "always" explained the procedure, in the month prior to the interview, and 21% health workers "almost always". Very similar frequencies are observed in Oio, where more than a half (64%) responded "always" having explained the procedures and 23% "almost always". Moreover, in this region, one health worker mentioned "rarely" having explained.

To the question of whether the health professional, in the last month, felt discontent with her/his work, half of professionals working in Bafatá health centers said to having felt "sometimes" discontent, although 32% of them, mentioned "never" have felt discontent the month before. "Never" having felt discontent, in Biombo, also comprised the greater proportion (36%) of these region's answers, and the same can be observed in Oio, where half (51%) of health professionals in this region chose this answer alike. Regarding how would the workers that responded "sometimes", "almost always" and "always" show their dissatisfaction to the patients, feeling but not showing his/her dissatisfaction was the most frequent stance adopted in Bafatá's health workers (55%). The same behavior was also more frequently adopted by Biombo's health professionals, albeit with a greater proportion, as reported by 89% of participants. In Oio, we notice that one health worker, as a demonstration of his/her dissatisfaction, charged for an otherwise free service.

Concerning possible difficulties felt when caring for women or children from a different ethnicity than the health worker, it was only in the Bafatá region where more than half (71%) of the health workers said to struggle. From the ones experiencing difficulties, health professionals in Bafatá and Oio said to confront the most with the communication with the women (being either because the woman only spoke a language that the health worker did not understand or she herself was not able to understand what was being said to her), with 12 health workers in the first region and eight in the second expressing this frustration. The second most common difficulty cited by professionals in Bafatá and Oio was the acceptance of women's health behaviors. Five health professionals in Bafatá and one in Biombo, in turn, said to experience both difficulties at the same time.

3.5 Factors associated with uptake of full childhood vaccination, four or more ANC visits and facility birth in bivariate analysis

The bivariate analysis, considering the Family group, Village and Sanitary Area clusters, revealed that type of health center, quality of infrastructure, maternal age, and household size were associated with **full childhood vaccination** (Table 14 a)). The number of days per week with ANC consultations available to women, the cost of the reproductive health card, quality of infrastructure of the health center, availability of evacuation vehicles and type of vehicle, distance to reference health center, birth order, maternal socioeconomic level, age, education, ethnicity, and household size were associated with **four or more ANC visits** (Table 15 a)). The quality of the health center's infrastructure, existence of pre/post-partum room exclusive to women, availability of evacuation vehicles and type of vehicle, distance to health center, season of the year, birth order, maternal socioeconomic level, education, age, ethnicity, attendance of at least one ANC visit, known history of facility delivery and household size are associated with **facility birth** (Table 16 a)). The bivariate analysis results of the three outcomes are summarized in more detail in *Supplementary information 5*.

3.6 Factors associated with uptake of full childhood vaccination, four or more ANC visits and facility birth in multivariate analysis

Four-level multivariate mixed effect logistic regressions were performed, with four models for each outcome. These models always consider the Family group, Village, and Sanitary Area as random intercepts (random effects), and the health center, village geographical, and child-maternal variables as fixed effect. Only statistically significant fixed effect variables in the unadjusted analysis entered their respective models.

Therefore, Model I is a random intercept model only, with no predictor variables, setting the initial random effect that is present on the children; in Model II, to the random effect clusters, only health center and village geographical variables were introduced; in Model III, to the random effect clusters, only the child-maternal variables were introduced; in Model IV, to the random effect clusters, the former health center, village geographical and child-maternal variables were introduced simultaneously.

3.6.1 Uptake of full childhood vaccination

The results of the fixed and random effects, as well as the measures of variance and fit are summarized in Table 14 a) and Table 14 b). Model IV, the model that includes the terms with the best combination of the variation and fit measures, is considered the model that better predicts full vaccination in children from Oio, Biombo and Bafatá.

In this model, **none of the variables** that showed association in the unadjusted analysis **remained statistically significant** when adjusted to one another, being either health center characteristics (type of health center, quality of infrastructure) or child-maternal characteristics (maternal age and household size). Although these variables do not have a

statistically significant individual contribution to the model, when included in the hierarchical contextual structure of Sanitary Area, Village and Family group, the measures of variation provide compelling information.

Comparing Model IV with Model I, we observe that in Model I, the null model, already indicates a significant variation of the likelihood of full vaccination in children between clusters related to upper-level variables, with a combined sum of the clustering effect across the different levels of 51%. In Model IV, more variation of full vaccination in children across clusters is explained by the child-maternal and health center characteristics included, as the total ICC reduces to 46%. Concurrently, adding both health center and child-maternal characteristics to the model, explained a meaningful proportion of the total variation (PCV of Model IV=44%), noting that adding health center characteristics to the null model alone (Model II) accounted for 38% of the total variation.

The Model IV's MOR also indicates that the between cluster variation was reduced with the added health center and child-maternal variables. Nevertheless, the final ICC and MOR persist in being higher and the PCV lower than expected. In other words, we anticipated that the inclusion of these variables in the final model would have been more effective in reducing the clustering effect. The Model IV's AUC is high, highlighting a good discriminatory power of the model containing individual and contextual information, and the lower AIC and BIC demonstrates that this model has a better fit alike.

Table 14 a). *Bivariate and multivariate multilevel logistic regression of health center, village geographical, and child-maternal characteristics associated with uptake of full childhood vaccination*

Uptake of full childhood vaccination (*n*=29 health centers)		**Model I (*n*=1,739)**	**Model II (*n*=1,739)**	**Model III (*n*=1,711) ***	**Model IV (*n*=1,711) ***
	uOR (80%CI)		**aOR (95% CI)**	**aOR (95% CI)**	**aOR (95% CI)**
Sanitary Area – Level (29 clusters)					
Health center characteristics					
Type of Health Center					
B	1		1		1
C	**2.28 (1.40, 3.71)**		1.85 (0.84, 4.10)		1.77 (0.79, 3.97)
Quality of infrastructure					
Reasonable	1		1		1
Good	**1.68 (1.18, 2.38)**		1.40 (0.80, 2.46)		1.48 (0.83, 2.62)
Bad	1.91 (0.79, 4.62)		1.60 (0.43, 5.97)		1.75 (0.45, 6.78)
Village - Level (172 clusters)					
Family group - Level (1,081 clusters)					
Child – Level					
Maternal socioeconomic, socio-demographic, and obstetric characteristics					
Age (years)					
< 19	1			1	1
>=19 to 25	0.99 (0.77, 1.29)			1.00 (0.67, 1.47)	0.99 (0.67, 1.46)
>=25 to 35	1.15 (0.89, 1.48)			1.18 (0.77,1.81)	1.19 (0.78, 1.82)
>=35	**0.71 (0.52, 0.98)**			0.87 (0.49, 1.53)	0.87 (0.50, 1.54)
Household size					
< 3 children	1			1	1
>=3 to 6 children	1.05 (0.89, 1.23)			0.99 (0.73, 1.34)	0.99 (0.73, 1.34)
>= 6 children	**0.55 (0.40, 0.76)**			0.57 (0.32, 1.03)	0.57 (0.32, 1.02)

Notes: ***28** missing observations (please refer to Table 5); uOR = unadjusted Odds Ratio; aOR = adjusted Odds Ratio; 80%CI = 80% Confidence Interval; 95%CI = 95% Confidence Interval. For uOR, *p* value was set at < 0.2, for Models II, III, and IV it was set at <=0.05

Table 14 b). *Measures of variation and fit for multivariate multilevel logistic regression of health center, village geographical and child-maternal characteristics associated with uptake of full childhood vaccination*

Uptake of full childhood vaccination	Model I (*n*=1,739)	Model II (*n*=1,739)	Model III (*n*=1,711) *	Model IV (*n*=1,711) *
Measures of variation				
ICC (%) [a]	51	45	52	**46**
Sanitary Area	7	5	7	**5**
Village< Sanitary Area	18	16	19	**17**
Family group <Village<Sanitary Area	26	24	26	**24**
PCV (%) [b]	Reference	38	1	**44**
MOR[c] **(95% CI)**	2.82 (2.00, 3.64)	2.67 (1.90, 3.43)	2.81 (1.96, 3.66)	**2.65 (1.86, 3.43)**
Measures of fit				
AIC[d]	2284.936	2284.954	2244.257	**2244.285**
BIC[e]	2306.781	2323.181	2293.261	**2309.623**
AUC[f] **(95% CI)**	0.85 (0.83-0.87)	0.84 (0.83-0.86)	0.84 (0.83-0.86)	**0.84 (0.82-0.85)**

Notes: *28 missing observations (please refer to Table 5) [a] Intercorrelation cluster (ICC) [b] Proportional Change in Variance (PCV) [c] Median Odds Ratio (MOR) [d] Akaike Information Criterion (AIC) [e] Bayesian Information Criterion (BIC) [f] Area Under the receiver operating characteristic Curve (AUC)

3.6.2 Uptake of four or more ANC visits

The results of the fixed and random effects, as well as the measures of variance and fit are summarized in Table 15 a) and Table 15 b). Considering all the measures of fit and variation, Model IV is the model that best explains the outcome of ANC uptake in Oio, Biombo and Bafatá. The interpretation of the adjusted OR in Model IV should be made considering the changes in the measures of variation when moving from Model I to Model IV. In the final model, lower-level variables such as **birth order** of the child, **maternal socioeconomic level**, **education, age,** and **ethnicity**, and upper-level variables namely, **cost of the reproductive health card**, **quality of infrastructure** of the health center and **distance to health center** show a statistically significant association with the likelihood of the mothers having completed four or more ANC visits.

Being the **second or third born** child was associated with a lower likelihood (aOR= 0.50, 95% CI: 0.37, 0.67) of their mothers having attended four or more ANC visits when

Table 15 a). *Bivariate and multivariate multilevel logistic regression of health center, village geographical, and child-maternal characteristics associated with uptake of four or more ANC visits*

Uptake of four or more ANC visits (*n*=29 health centers)		**Model I (*n*=3,419)**	**Model II (*n*=3,373) ***	**Model III (*n*=3,147) ***	**Model IV (*n*=3,104) ***
	uOR (80%CI)		**aOR (95% CI)**	**aOR (95% CI)**	**aOR (95% CI)**
Sanitary Area – Level (29 clusters)					
Health center characteristics					
ANC consultations (nº of days/week)					
5	**1**		1		1
7	**0.50 (0.28, 0.88)**		0.68 (0.31, 1.50)		0.62 (0.30,1.30)
Reproductive Health Card cost					
No cost	1		1		1
Fixed cost	0.87 (0.58, 1.31)		0.68 (0.41, 1.14)		**0.60 (0.38, 0.96)**
Unfixed/unknow cost	**1.98 (1.04, 3.78)**		1.91 (0.77, 4.74)		1.37 (0.59, 3.16)
Quality of infrastructure					
Reasonable	1		1		1
Good	1.17 (0.84, 1.62)		1.22 (0.73, 2.02)		1.12 (0.70, 1.77)
Bad	**0.25 (0.10, 0.60)**		0.16 (0.04, 0.54)		**0.21 (0.06, 0.71)**
Evacuation vehicles and type of vehicle					
No vehicle	1		1		1
Yes, ambulance	1.14 (0.79, 1.64)		0.67 (0.39, 1.17)		0.64 (0.37, 1.09)
Yes, motorcycle	**0.52 (0.27, 0.99)**		0.45 (0.17, 1.14)		0.53 (0.21, 1.32)
Village - Level (180 clusters)					
Village geographical characteristics					
Distance to health center (km)					
< 2km	1		1		1
>=2 to 5km	**0.56 (0.40, 0.79)**		0.53 (0.31, 0.90)		0.60 (0.35, 1.03)
>=5 to 8km	**0.62 (0.44, 0.87)**		0.56 (0.33, 0.97)		0.75 (0.43, 1.33)
>=8km	0.49 (0.35, 0.68)		0.41 (0.25, 0.70)		**0.51 (0.30, 0.89)**
Family group - Level (1,589 clusters)					
Child – Level					
Child socio-demographic characteristics					
Birth order					
1st	1			1	1
2nd or 3rd	**0.66 (0.56, 0.77)**			0.51 (0.38, 0.69)	**0.50 (0.37, 0.67)**
4th or 5th	**0.62 (0.52, 0.73)**			0.36 (0.23, 0.55)	**0.35 (0.23, 0.55)**
>=6th	**0.51 (0.43, 0.60)**			0.27 (0.16, 0.45)	**0.26 (0.16, 0.45)**
Maternal socioeconomic, socio-demographic, and obstetric characteristics					
Socioeconomic level					
Level 0-2	1			1	1
Level 3	1.01 (0.84, 1.39)			1.09 (0.73, 1.62)	1.09 (0.73, 1.63)
Level 4	**1.41 (1.12, 1.78)**			1.35 (0.94, 1.96)	1.34 (0.93, 1.94)
Level 5	**1.67 (1.32, 2.12)**			1.61 (1.10, 2.34)	**1.60 (1.10, 2.33)**

Uptake of four or more ANC visits (*n*=29 health centers) (continuation)	uOR (80%CI)	Model I (*n*=3,419)	Model II (*n*=3,373) * aOR (95%CI)	Model III (*n*=3,147) * aOR (95% CI)	Model IV (*n*=3,104) * aOR (95% CI)
Education (years)					
No formal education	1			1	1
>=1 to 4	**1.21 (1.05, 1.40)**			1.14 (0.90, 1.45)	1.17 (0.92, 1.49)
>=4 to 6	**1.55 (1.33, 1.81)**			1.47 (1.13, 1.90)	**1.46 (1.12, 1.90)**
>=6	**1.62 (1.36, 1.93)**			1.49 (1.11, 2.02)	**1.45 (1.07, 1.97)**
Age (years)					
< 19	1			1	1
>=19 to 25	**0.81 (0.68, 0.98)**			1.19 (0.84, 1.68)	1.18 (0.84, 1.67)
>=25 to 35	0.85 (0.71, 1.02)			2.06 (1.37, 3.09)	**2.07 (1.37, 3.11)**
>=35	**0.80 (0.64, 1.00)**			2.92 (1.76, 4.85)	**2.99 (1.80, 4.97)**
Ethnicity					
Fula	1			1	1
Mandinga	0.87 (0.68, 1.11)			0.90 (0.61, 1.31)	0.83 (0.56, 1.23)
Balanta	**0.60 (0.44, 0.84)**			0.57 (0.34, 0.96)	0.60 (0.35, 1.02)
Pepel	1.40 (0.97, 2.02)			1.38 (0.76, 2.50)	1.15 (0.62, 2.13)
Manjaco/Mancanha	1.67 (0.87, 3.21)			1.10 (0.38, 3.15)	1.07 (0.38, 3.05)
Other/Multi-ethnic	0.63 (0.39, 1.02)			0.49 (0.23, 1.06)	**0.44 (0.20, 0.95)**
Household size					
< 3 children	1			1	1
>=3 to 6 children	**0.83 (0.75, 0.93)**			1.08 (0.76, 1.55)	1.08 (0.75, 1.56)
>= 6 children	**0.63 (0.51, 0.79)**			0.89 (0.52, 1.52)	0.85 (0.49, 1.46)

Notes: For missing observations please refer to Table 7 and 8

Table 15 b). *Measures of variation and fit for multivariate multilevel logistic regression of health center, village geographical, and child-maternal characteristics associated with uptake of four or more ANC visits*

Uptake of four or more ANC visits	Model I (*n*=3,419)	Model II (*n*=3,373) *	Model III (*n*=3,147) *	Model IV (*n*=3,104) *
Measures of variation				
ICC (%) [a]	51	39	43	**35**
Sanitary Area	7	3	5	**2**
Village< Sanitary Area	17	13	13	**10**
Family group <Village<Sanitary Area	27	23	25	**23**
PCV (%) [b]	Reference	69	37	**78**
MOR[c] (95% CI)	2.88 (2.32, 3.44)	2.58 (2.12, 3.04)	2.74 (2.20, 3.28)	**2.56 (2.08, 3.04)**
Measures of fit				
AIC[d]	4362.411	4295.903	3982.387	**3926.335**
BIC[e]	4386.96	4381.633	4121.633	**4125.669**
AUC[f] (95% CI)	0.84 (0.82-0.85)	0.83 (0.82-0.84)	0.85 (0.86-0.86)	**0.85 (0.83-0.86)**

Notes: For missing observations please refer to Table 7 and 8

compared with a first-born child; these odds were also lower for the **fourth or fifth born** child (aOR= 0.35, 95% CI: 0.23, 0.55) and for a child that was the **sixth child or above** (aOR= 0.26, 95% CI: 0.16, 0.45).

Children whose mothers' **socioeconomic level is the highest** (Level 5) have higher odds (aOR= 1.60, 95% CI: 1.10, 2.33) of their mothers having completed four or more ANC visits compared with those who are categorized in Levels 0 to 2. Increased maternal education is also associated with higher likelihood of the mother having completed four or more ANC visits: children whose mothers studied **between 4 and 6 years in school** or **6 years or more** have 1.46 and 1.45 higher odds, respectively (95% CI: 1.12, 1.90; 95%CI: 1.07, 1.97), of their mothers having had four or more ANC visits when compared with mothers with no formal education. The odds of the mother having had four or more ANC visits during pregnancy increases in higher age groups in comparison with the lowest age group: children of mothers between **25 and 35 years of age** have higher odds (aOR=2.07, 95% CI: 1.37, 3.11) of having four or more ANC visits, as well as mothers with **35 years of age and above** (aOR=2.99, 95% CI: 1.80, 4.97), when compared with mothers with less than 19 years of age. Children whose mothers are **multi-ethnic** or categorized in the **other ethnicities** category have lower likelihood (aOR= 0.44, 95% CI: 0.20, 0.95) of their mothers having attended four or more ANC visits when compared with Fula mothers. The aOR for birth order, maternal socioeconomic level, ethnicity and education were slightly lower in Model IV, comparing to Model III (the model without the inclusion of health center and village characteristics) and maternal age slightly higher, which may be indicating that the contextual variables were accounting for some of the effect of the child-maternal variables, albeit in an almost negligeable manner.

Regarding the health center and village geographical characteristics adjusted for child-maternal characteristics, the probability of the child having a mother that attended four or more ANC visits during her pregnancy is associated with **cost of the reproductive health card**, **quality of infrastructure** and **distance to health center**. Children whose villages were covered by a reference health center that charged a **fixed cost** for the mother's reproductive health card had lower odds (aOR=0.60, 95% CI: 0.38, 0.96) of their mother having had four or more ANC visits compared with children/mothers whose health centers did not charge for

the card. Children whose villages were covered by health centers that received the classification **"bad" in respect to the quality of the infrastructure**, have lower odds (aOR=0.21, 95% CI: 0.06, 0.71) of their mothers having attended four or more ANC visits when compared with health centers classified as "reasonable" by the health professionals. Children whose villages are **8km or more** from their reference health center have a lower likelihood (aOR=0.51, 95% CI: 0.30, 0.89) of their mothers having attended four or more ANC visits, when compared with children whose mothers live in a village less than 2km away from the reference health center. Similarly to what occurred in the child-maternal characteristics when adjusted for the health center and village characteristics, the aOR of number days per week of ANC consultation, the cost of the reproductive health card and quality of infrastructure decreased when going from Model II (health center and village characteristics) to Model IV (where child-maternal characteristics were added to health center and village geographical characteristics), and distance to health center increased, though almost imperceptible.

The high initial ICC in Model I demonstrated the necessity of a multilevel model, as 51% of the variation in the likelihood of having four or more ANC visits is due to differences between clusters. The Model IV is the model where the clustering effect is most reduced (ICC=35%). The addition in Model IV of the upper-level variables (health center characteristics and distance to health center) and the lower-level variables (child-maternal characteristics), explained 78% of the variation of the likelihood of the mother having completed four or more ANC visits, a substantial proportion. Likewise, the MOR decreases the most in the final model, pointing towards a decrease heterogeneity between clusters derived from the added terms. Model IV's AUC is also one of the highest, indicating a high discriminatory accuracy of the model, which also presents the lowest AIC and the second lowest BIC.

Finally, an important aspect to add is that number of **days per week of ANC consultations** available at the health center, availability of **evacuation vehicles and type of vehicle** and **household size**, individually, did not present a statistically significant association with uptake of four or more ANC visits. Nevertheless, as they are included in the model that best captured the variability in the outcome, they may have contributed to the overall reduction of the clustering effect and must be acknowledged as well.

Sensitivity analysis of uptake of four or more ANC visits

This outcome required a sensitivity analysis given the proportion of women whose number of ANC visits is unknown. First, a chi-square test of independence was performed to assess if significant differences between background factors of children/mothers with and without information on the number of ANC visits existed. In total, 3,419 children/mothers (75%) had information on number of ANC visits and 1,137 (25%) children/mothers had missing information. The chi-square's *p* value demonstrated that the differences in the percentage of waiting times for ANC consultation, out-of-stock and free-of-charge medicine, quality of infrastructure, distribution of mosquito net, maternal socioeconomic level, ethnicity, education, distance to the reference health center, and household size between the two groups were statistically significant. This significant difference between the background factors of the women/children with and without missing number of ANC visits, prompted the employment of a sensitivity analysis for the assessment of the robustness of the results of the main ANC analysis.

This sensitivity analysis was conducted substituting the 1,137 missing number of ANC visits with extreme values, specifically assuming two scenarios: a) considering all the missing ANC visits as less than four ANC visits and b) considering all the missing ANC visits as four or more ANC visits. Then, the same statistical methodology already described in the corresponding chapter, was conducted for each scenario (measures of fit were excluded, as the sole purpose was to identify possible effect size changes).

In *Supplementary Information 6*, the chi-square statistics as well as the bivariate and multivariate multilevel mixed-effects logistic regressions of the sensitivity analysis for the two approaches can be found.

Approach a) Replacing all missing number of ANC visits as less than four ANC visits

Very similar to the main ANC coverage analysis, number of days per week of ANC consultations, reproductive health card cost, quality of infrastructure, availability of evacuation vehicles and type of vehicle, distance to health center, birth order, maternal socioeconomic level, education, ethnicity, and household size, all presented statistical significance in the multilevel bivariate analysis. We highlight that the effect sizes, though

slightly different since the sample size increased, continue to be within the same direction of association.

Only maternal age, which is a significant predictor in the main ANC analysis, is not correlated with the likelihood of obtaining four or more ANC visits. Therefore, and following the same underlying assumptions of the statistical methodology used, this variable was excluded from the multivariate analysis. We note, however, that the 95% CI of the age categories of 19 and 25 years and 35 years and above are very close to 1.

In the multilevel multivariate analysis, we observe that Model IV is also the Model with the best measures of variation: the ICC reduces by 14% from Model I to IV, and the Model IV PCV accounts for 96% of the variation between the clusters. The MOR is also its lowest in final Model. All the explanatory variables in the main ANC's Model IV who were statistically significant (of course, excluding maternal age) are also significant predictors in the ***Approach a)***. Again, with some expected variation in the effect sizes, all the significant predictors of Model IV have the same direction of association as in the main model. Hence, we establish that these results do not alter the conclusions of the main ANC analysis' findings.

Approach b) Replacing all missing number of ANC visits as four or more ANC visits

Approach b) yielded similar results. Distance to health center, birth order, maternal socioeconomic level, education, age, ethnicity, and household size were statistically significant in the multilevel bivariate analysis. Indeed, no health center characteristic in the unadjusted analysis was correlated with four or more ANC visits yet, the explanatory variables that are significant predictors in the main analysis ANC (number of days per week of ANC consultations, the cost of the reproductive health card, quality of infrastructure, existence of evacuation vehicles and type of vehicle) have a 95% CI tendentially close to 1 in ***Approach b)***. The multilevel multivariate analysis followed, this time without any health center characteristic. Model IV is the best model, as confirmed by the measures of variation. Model's IV ICC is the lowest at 27%, 37% of the heterogeneity between clusters is accounted for, and the MOR is the lowest. Interpreting the fixed OR, we observe that birth order, maternal socioeconomic level, education, and age remain significant, just as in the main ANC

analysis. The effect sizes maintain the same direction. Distance to health center and ethnicity had no categories correlated with four or more ANC visits but showed the same direction of association. Therefore, we also conclude that ***Approach b)*** did not considerably change the interpretations of the main ANC analysis.

The measures of variation did not show the same magnitude as in the main analysis, but, overall, results were similar to the main ANC coverage analysis.

3.6.3 Uptake of facility birth

The results of the fixed and random effects, as well as the measures of variance and fit are summarized in Table 16 a) and Table 16 b). Considering all the measures of fit and variation, as expected, Model IV is the model that best explains facility birth uptake. In this model, upper-level variables such as **quality of infrastructure**, availability of **evacuation vehicles and type of vehicle** and **distance to health center**, and lower-level variables, namely **season of the year**, **birth order** of the child, **maternal age** and **known history of facility delivery** are associated with the probability of giving birth at a health facility.

When adjusted for the effect of the health center and village characteristics, a child born during the **rainy season** had higher odds (aOR=1.20, 95% CI: 1.01, 1.43) of being born in a health facility than a child born during the dry season. The **second or third child** born to their mothers had lower likelihood (aOR=0.14, 95% CI: 0.10, 0.20) to being born in a health facility compared with the first born child, the same effect being observed with the **fourth or fifth** (aOR=0.10, 95% CI: 0.06, 0.17) and **sixth child or above** (aOR=0.12, 95% CI: 0.07, 0.21) The probability of being born in a health facility increases with the age groups: children born to women aged between **25 and 35 years** and aged **35 years and above** had 1.82 and 1.90 higher odds, respectively (95% CI: 1.21, 2.73; 95% CI: 1.14, 3.14) of being delivered at a health facility when compared with mothers aged less than 19 years. Children whose **older siblings were confirmed to be born at home** or that are **their mother's first child** have lower likelihood (aOR=0.40, 95% CI: 0.29, 0.55) of having been born at a health facility when compared with children whose older siblings were confirmed to be born at a health

Table 16 a). *Bivariate and Multivariable multilevel logistic regression analysis of health center, village geographical, and child-maternal characteristics associated with uptake of facility birth*

Uptake of facility birth (*n*=27 health centers)	uOR (80%CI)	Model I (*n*=3,682)	Model II (*n*=3,651) * aOR (95% CI)	Model III (*n*=3,348) * aOR (95% CI)	Model IV (*n*=3,322) * aOR (95% CI)
Sanitary Area – Level (27 clusters)					
Health center characteristics					
Quality of infrastructure					
Reasonable	1		1		1
Good	0.92 (0.66, 1.29)		0.90 (0.62, 1.29)		0.97 (0.67, .39)
Bad	**0.29 (0.13, 0.64)**		0.17 (0.07, 0.42)		**0.21 (0.08, .56)**
Pre/post-partum room exclusive for women					
Yes	1		1		1
No	**0.57 (0.35, 0.92)**		1.03 (0.65, 1.63)		0.92 (0.59, 1.42)
Evacuation vehicles and type of vehicle					
Yes, ambulance	1		1		1
Yes, motorcycle	**0.16 (0.09, 0.30)**		0.23 (0.10, 0.53)		**0.30 (0.13, 0.71)**
No vehicle	**0.54 (0.40,0.73)**		1.02 (0.67, 1.55)		1.11 (0.73, 1.68)
Village - Level (145 clusters)					
Village geographical characteristics					
Distance to health center (km)					
< 2 km	1		1		1
>=2 to 5km	**0.42 (0.29, 0.63)**		0.48 (0.27, 0.85)		**0.49 (0.28, 0.88)**
>=5 to 8km	**0.34 (0.23, 0.50)**		0.37 (0.20, 0.66)		**0.42 (0.23, 0.77)**
>=8 km	**0.23 (0.16, 0.34)**		0.23 (0.13, 0.40)		**0.27 (0.15, 0.51)**
Family group - Level (1,480 clusters)					
Child – Level					
Child socio-demographic characteristics					
Season of the year					
Dry season	1			1	1
Rainy season	**1.28 (1.16, 1.43)**			1.21 (1.01, 1.44)	**1.20 (1.01, 1.43)**
Birth order					
1st	1			1	1
2nd or 3rd	**0.25 (0.21, 0.30)**			0.14 (0.09, 0.19)	**0.14 (0.10, 0.20)**
4th or 5th	**0.21 (0.18, 0.25)**			0.10 (0.06, 0.16)	**0.10 (0.06, 0.17)**
>=6th	0.26 (0.22, 0.32)			0.11 (0.07, 0.20)	**0.12 (0.07, 0.21)**
Maternal socioeconomic, socio-demographic, and obstetric characteristics					
Socioeconomic level					
Level 0-2	1			1	1
Level 3	0.92 (0.74,1.15)			0.90 (0.62, 1.29)	0.89 (0.61, 1.27)
Level 4	1.14 (0.93, 1.40)			1.20 (0.85, 1.68)	1.17 (0.83, 1.64)
Level 5	**1.34 (1.08, 1.65)**			1.35 (0.95, 1.92)	1.32 (0.93, 1.87)
Education (years)					
No formal education	1			1	1
>=1 to 4	1.05 (0.91, 1.21)			0.85 (0.67, 1.08)	0.85 (0.67, 1.08)
>=4 to 6	**1.32 (1.13, 1.53)**			1.04 (0.80, 1.36)	1.01 (0.78, 1.32)
>=6	**1.63 (1.37, 1.95)**			1.33 (0.98, 1.81)	1.30 (0.95, 1.78)

Uptake of facility birth (*n*=27 health centers) (continuation)	uOR (80%CI)	Model I (*n*=3,682)	Model II (*n*=3,651)* aOR (95% CI)	Model III (*n*=3,348) * aOR (95% CI)	Model IV (*n*=3,322) * aOR (95% CI)
Age (years)					
< 19	1			1	1
>=19 to 25	**0.48 (0.40,0.58)**			1.17 (0.83, 1.64)	1.14 (0.81, 1.60)
>=25 to 35	**0.42 (0.36, 0.51)**			1.87 (1.24, 2.80)	**1.82 (1.21, 2.73)**
>=35	**0.40 (0.33, 0.50)**			1.97 (1.19, 3.27)	**1.90 (1.14, 3.14)**
Ethnicity					
Fula	1			1	1
Mandinga	1.09 (0.84, 1.41)			1.02 (0.68, 1.53)	1.04 (0.71,1.54)
Balanta	**0.70 (0.52, 0.94)**			0.55 (0.34, 0.88)	0.79 (0.46,1.36)
Pepel	**2.43 (1.76, 3.37)**			2.08 (1.26, 3.43)	1.20 (0.69,2.08)
Manjaco/Mancanha	**2.37 (1.05, 5.33)**			1.17 (0.31, 4.36)	1.35 (0.37, 4.92)
Other/Multi-ethnic	1.66 (0.99, 2.78)			1.28 (0.56, 2.94)	1.21 (0.53, 2.76)
Mother attended at least one ANC consultation					
Yes	1			1	1
No / Doesn't know	**0.75 (0.59, 0.95)**			0.74 (0.49, 1.12)	0.73 (0.49, 1.11)
Known history of facility delivery					
Yes	1			1	1
No/Primigravidae	**1.28 (1.11, 1.48)**			0.38 (0.28, 0.53)	**0.40 (0.29, 0.55)**
Unknow	**0.67 (0.59, 0.75)**			0.55 (0.45, 0.68)	**0.56 (0.46, 0.69)**
Household size					
< 3 children	1			1	1
>=3 to 6 children	**0.60 (0.53, 0.67)**			0.81 (0.60, 1.14)	0.79 (0.56, 1.10)
>= 6 children	**0.78 (0.63, 0.96)**			0.95 (0.57, 1.58)	0.90 (0.54, 1.50)

Notes: *For missing observations please refer to Table 9 and 10

Table 16 b). *Measures of variation and fit for multivariate multilevel logistic regression of health center, village geographical, and child-maternal characteristics associated with uptake of facility birth*

Uptake of facility birth	Model I (*n*=3,682)	Model II (n=3,651) *	Model III (n=3,348) *	Model IV (n=3,322) *
Measures of variation				
ICC (%)[a]	59	37	39	**33**
Sanitary Area	5	1.61e-29	7.05e-31	**1.270e-33**
Village< Sanitary Area	22	13	14	**11**
Family group <Village<Sanitary Area	32	24	25	**22**
PCV (%) [b]	Reference	31	21	**49**
MOR[c] (95% CI)	3.25 (2.62, 3.87)	2.57 (2.14, 3.00)	2.73 (2.22, 3.24)	**2.47 (2.02, 2.92)**
Measures of fit				
AIC[d]	4627.464	4559.273	4021.559	**3972.905**
BIC[e]	4652.309	4627.504	4180.593	**4180.588**
AUC[f] (95% CI)	0.84 (0.83-0.85)	0.83 (0.82-0.85)	0.85 (0.84-0.87)	**0.85 (0.84-0.86)**

Notes: *For missing observations please refer to Table 9 and 10

facility; similarly, children whose older siblings have an **unknown place of birth** has also lower odds (aOR=0.56, 95% CI: 0.46, 0.69) of having been born at a health facility. Like in the outcome of ANC uptake, the aOR of season of the year, birth order, and age slightly reduce between Model III and Model IV and known history of facility delivery slightly increased, indicating that these variables could have been capturing some contextual effect, albeit, also here, almost negligible.

In respect to the health center and village characteristics, a child whose village is covered by a health center classified as having "**bad" quality of infrastructure** has lower odds (aOR=0.21, 95% CI: 0.08, 0.56) of being born at a health facility in comparison with a child whose village is covered by a health center classified as having "reasonable" quality of infrastructure. Children whose mothers resided in a village that is served by a health center that possesses a **motorcycle as an evacuation vehicle**, had a lower likelihood (aOR=0.30, 95% CI: 0.13, 0.71) of being delivered at a health facility in comparison to a child whose reference health center possessed an ambulance as an emergency vehicle. Living in a village more than 2km away from a health center was also significantly associated with the probability of being born outside a health facility: residing between **2 to 5km from the health center** lowered the likelihood of being born at a health facility (aOR=0.49, 95% CI: 0.28, 0.88), as well as **living 5 to 8km** (aOR=0.42, 95% CI: 0.23, 0.77) and **8km or more** away (aOR=0.27, 95% CI: 0.15, 0.51), when compared to a child whose mother resided less than 2km from the health center. Also, very similarly to the ANC outcome, is how the aOR of quality of infrastructure, evacuation vehicles/type of vehicle and distance to health center decreased, in the first variable, and increased, in the remaining variables, when going from Model II (only health center and village geographical variables) to Model IV (health center, village geographical, and child-maternal variables). However, also here the adjustments to the health center and village variables are not remarkable.

Concerning the measures of variation, facility birth uptake had the highest initial ICC in comparison to the other outcomes (ICC=59%), and whose final Model included terms that were able to reduce the ICC to the lowest value of 33%. The variables included in Model IV also helped explain 49% of the variation of the probability of being born at a health facility. The MOR decreased with each model, being the lowest in the final one, meaning that

clustering effect was reduced the most with health center, village geographical, and child-maternal variables. Regarding the measures of fit, AIC and BIC were the lowest in the final model, showing that this model had the best fit as well. Model IV's high AUC suggests a high accuracy in determining whether the child was born at a health facility or not.

No statistical evidence was found of availability of a **pre/post-partum room exclusive for women**, **evacuation and type of vehicle**, **maternal socioeconomic level**, **education**, **ethnicity**, and **attendance of at least one ANC visit** having an association with the outcome of facility birth. However, as they are included in the model that best reduces the cluster effect while having the best fit, they may have their contribution of reducing the variance between clusters as well.

The models equations for the multilevel multivariate mixed-effects logistic regression are indexed in *Supplementary Information 7.*

4. Discussion

High MMR and U5MR in Guinea-Bissau led to the introduction of PIMI in 2011- at first only in four regions of the country and nationwide in 2017 (33). Increasing the access, uptake and coverage of MCHS, namely childhood vaccination, ANC visits and facility births was one of the strategies to reduce these mortality ratios (23). Supporting NGO's were responsible for supplying medical materials and medicines, providing training to health staff and monetary incentives for completion of MCHS indicators, and supporting the economic cost derived from the user fee waivers (23, 33). This study was timewise inserted during PIMI-III, which began in June 2022, and set out to assess with demand-side (child and woman) and supply-side (health center and village geographical) characteristics were associated with higher uptake of full childhood vaccination, four or more ANC visits and facility birth and impact their coverage. As the HDSS and health center data had a hierarchical structure and clustering effect, a four-level mixed effects logistic regression was used.

Overall, full childhood vaccination, uptake of four or more ANC visits and facility births are still far from being universal in the Bissau-Guinean regions of Bafatá, Biombo and Oio. Full vaccination coverage in children born between 1st of January 2020 and 1st of January 2021 was of 54%, higher than the reported WHO-UNICEF cross-country coverage for the year 2021 (34%), but lower than the 2020 estimate (67%) (134) (differences in estimates may be due to the use of vaccination years (instead of birth-cohort, as here used), and to the denominator used in these administrative reports provided by health services). Coverage of four or more ANC visits for children born between 1st of January 2021 and 1st of January 2023 and residing in these areas, fared even worse at 41%. The most recent data at a national level from 2017-2019, estimated a coverage of four or more ANC visits of 56% (117). Overall facility birth coverage of children born between 1st of January 2021 and 1st of January 2023 also remained at just 48% in the three regions. For comparison, coverage estimations from 2017-2019 calculated a national coverage of facility births of 49% (117).

It is necessary to acknowledge the external and internal events that affected Guinea-Bissau during the period between 1st of January 2021 and 1st of January 2023 and that certainly had their impact on the provision of MCHS in an already vulnerable country. Events like the COVID-19 pandemic (132, 135), vaccine shortages of BCG, OPV and tetanus in 2020 (136), frequent health workers' strikes claiming for better working conditions (136), a dismissal of a large part of the health working force in 2020 (136) and an attempt of a coup d'état in February 2022 (136) may have led to a disruption in the supply-side of MCHS and consequently contribute to explain the low coverages.

4.1. Uptake of full childhood vaccination

The type of health center, quality of the infrastructure, maternal age, and household size, were not statistically significantly associated with full childhood vaccination. Evidence of maternal age (137), household size (138) and quality of health center infrastructure (139) being a significant predictor of uptake of childhood vaccination was previously identified, but none of the studies accounted for clustering effect and/or adjusted for upper-level/contextual variables.

Though we did not estimate the statistical power for this outcome, as it would be lower than 80%, we do not expect that a larger power would ensure statistically significant differences, since some of the estimated CI were tendentially close to 1. Hence, the results of this study may indicate that a possible significant effect of the variables was not only being captured by the clusters but, at the same time, also being confounded by the other upper and lower-level characteristics included in the models. Nevertheless, these variables were able to explain some cluster effect, as the measures of variation show. With that stated, a significant amount of heterogeneity, namely at the level of contextual variables, continues to be unexplained.

In fact, each health center has included in their package of services, community outreach. When doing community outreach, health professionals travel to the farthest villages to vaccinate children (26). We hypothesize that the number of days per week of outreach to the community may be significantly associated with full childhood immunization or, at least, help in explaining more cluster variation. Moreover, restrictive vial-opening policies that

lead to delays in vaccination or under-vaccination of children are still applied in the country for vaccines such as BCG (94) and measles (95). These national guidelines may have affected the likelihood of the child being fully vaccinated. However, to mitigate the negative effects of this policy, health centers seek to aggregate a minimum number of children on the same day at the health center to justify opening a vial of BCG or measles (94, 95). Health centers then use CHW to not only communicate to their villages the days of BCG or measles vaccination at the health center/community outreach but also to help share information among the villagers about the advantages of vaccination (26). Therefore, it is also theorized that the number of CHW and/or their effectiveness may be relevant to explain uptake of full childhood vaccination.

The third contextual variable that may impact further full childhood vaccination, are strikes at the health centers. Health workers strikes due to poor working conditions are frequent in Guinea-Bissau and did happen during 2020 to 2021, period where the cohort-children were eligible for vaccination (in 2020 the government also dismissed a large part of the health working force) (136). During the data collection months, one health worker strike that lasted one week was observed. In this sample of health professionals, only 9% of the workers - a non-expected low prevalence - were absent due to striking and thus, an association between number of health workers striking and likelihood of full childhood vaccination was not possible to be investigated.

The last contextual variable that needs to be addressed, concerns the vaccination shortages in Guinea-Bissau, which are not uncommon. Nonetheless, national vaccines stock-outs were particularly severe in 2020 and 2021: for example, the duration of BCG stock-out in 2020 was of 3 months and in 2021 of 12 months and the duration of the OPV stock-out in 2021 was of 12 months (131). This fact probably drove to delays in vaccination - yet according to the criteria used to calculate vaccination coverage in this study, the child would be still considered as being fully vaccinated or – to lower access to it, provided that vaccinating children older than 12 months is considered wastage, as it doesn't count for countrywide indicators (95). These children, consequently, were classified in this study as not fully vaccinated. Furthermore, in the period of data collection, a national vaccination campaign

was conducted, after which all visited health centers had OPV stock-outs. We also want to recall the structural challenges faced at the health centers, where 17% of health center's responsible persons reported missing or insufficient freezers, and 23% lack of or unstable electricity sources, raising doubts about the safety of the cold chain at these health centers. Field reports mention that health professionals sometimes must go through great extents to conserve the vaccines in case of unstable electricity, namely using ice packs or transferring the vaccines to other health centers with functioning fridges.

4.2 Uptake of four or more ANC visits

The cost (or expected cost) of the reproductive card was associated with a reduced uptake of four or more ANC visits. That is, mothers whose village was covered by a health center that charged fixed costs for this card had a lower likelihood of completing four or more ANC visits when compared to mothers who lived in villages whose reference health center did not charge a fee. Unpredictability of fees, in fact, was a concern expressed by Bissau-Guinean women in a previous study alike (117). Studies conducted in LMIC's settings focused on associations between maternal socioeconomic status and use of MCHS (higher socioeconomic status conduces to higher MCHS uptake) (140, 141), however, the association between the existence of these (predictable) fees and MCHS uptake remains unstudied. This health center characteristic was observed in the field: although regional guidelines exist, health centers and health professionals tend to develop their own procedures, and these costs seemed more dependent on the health professional's decision than the health center itself in Guinea-Bissau, as previously reported (118).

Quality of infrastructure was also a significant predictor of four or more ANC visits in this study, with evidence of the same association in other LMIC (142, 143). In these cases, women's negative assessment of the infrastructure of the health facility was a deterrent for ANC visits. Being that this study did not obtain the women's perspective, the health professionals were asked to classify the infrastructure of their own health centers and this variable plotted against uptake of ANC. Since women whose reference health center were classified as "bad" by the health workers had a lower likelihood of completing four or more ANC visits in comparison to women whose health centers were classified as "reasonable" by

the health professionals, it may be that both women and health professionals' perspective on quality of the health center's infrastructure in the studied regions, is aligned.

Distance to health center was a significant predictor of uptake of four or more ANC visits in the three regions, which is consistent with other Bissau-Guinean report (117): living in a village 8km or more from the reference health center was associated with 49% lower likelihood of having four or more ANC visits, in comparison with living less than 2km away. This finding is supported by evidence from other sub-Saharan and east-African countries (49, 144, 145). Geographical accessibility, particularly for women in an advanced stage of pregnancy, may be coupled with other accessibility barriers such as road, see or river conditions (field reports detailed how some Bissau-Guinean women had to cross rivers to reach a health facility), and also with affordability of travel costs (49). To attempt to minimize this barrier, during community outreach in Guinea-Bissau, some health professionals provide ANC visits directly in the village, though in a much lower scale than childhood vaccinations (26).

Birth order of the child was also significantly associated with four or more ANC visits, the higher the birth order, the more reduced were the odds of the mother having had four or more ANC visits. The same evidence was detected in eastern and sub-Saharan Africa (140, 141, 145). Primigravidae may have higher risk perception or be more afraid than women who had several births (146), or parents may be more excited with their first-borns than with the subsequent pregnancies (147), and thus, use more ANC.

Uptake of ANC visits was the only outcome in which ethnicity was a statistically significant predictor variable. Compared with children whose mothers were from the Fula ethnic group, children whose mothers were from other smaller ethnic groups of multi-ethnic had lower odds of attending four or more ANC visits. Ethnic inequities in ANC coverage were also found in other west-African countries (140, 148). As mentioned before, ethnic-cultural beliefs may help explain these results, though it is also plausible that other predictors such as affordability or accessibility of the healthcare system between women from different ethnic groups may play a role (148).

Increased maternal age significantly increased the coverage of ANC: women aged between 25 to 35 years had more than twofold higher odds and women aged 35 years or above almost

threefold higher odds of completing four or more ANC visits, in comparison with women aged less than 19 years, with other sub-Saharan countries verifying the same direction of association (106, 149). This is possibly a result of older women perceiving a higher risk with their pregnancies or, on the contrary, younger women perceiving less risks (106). The effect of this variable is, nevertheless, contradictory in the literature. One pooled analysis of 32 sub-Saharan countries actually detected an inverse association, as women of older reproductive age had lower odds of ANC attendance, with the authors suggesting that older women had more birthing experience and therefore perceived less value in using ANC services (144). These explanations may point to parity being a factor affecting the association between maternal age and uptake of ANC visits, perhaps leading to contradictory results.

Maternal education was positively associated with uptake of ANC visits, since women who studied between 4 years or more in school had about 40% likelihood of completing four or more ANC visits, compared with women with no formal education. As observed by other studies in sub-Saharan Africa, mothers with increased education may have increased knowledge of the importance of ANC (thus higher risk perception), or higher agency and autonomy in decision-making, or also higher socioeconomic status than women with no formal education (145, 146, 150).

Indeed, belonging to the highest maternal socioeconomic level (Level 5) was significantly associated with four or more ANC visits, in comparison with women who were included in the Levels 0 to 2. This association is consistent with other findings in other sub-Saharan African countries (151, 152, 153) and may be a reflection of maternal education and occupation (151). The data collected at the health centers identified that in all health centers, ANC visits had, reportedly, no cost for the pregnant woman. Besides the fees of reproductive health cards in 26% of the here-studied health centers, indirect costs of transportation (152) and opportunity costs (153) could in part explain this association.

Number of days per week of ANC consultations at the health center, availability of evacuation vehicles and type of vehicle and household size, albeit not statistically significant, also contributed to reduce variance between clusters. Despite the previous evidence of household size as a significant predictor of ANC in African countries (49, 148), the association was not being analyzed accounting for cluster effect in the studied regions and

adjusting for upper-level/contextual variables. The possible significant effect of these variables in this study may have been attributed to the clusters themselves and, concurrently, to the confoundment with other variables included in the models. Despite that, the measures of variation still indicate some clustering effect left, indicating the necessity of continuing exploring other possible predictor variables. For example, future studies may want to consider the effectiveness of the CHW's role in MCHS. CHW may be very active participants not only in improvement of childhood vaccination, but also in improvement of the uptake of ANC visits (154, 155) in the villages that they serve.

Although the variables lack of instruments for ANC consultation and out-of-stock and free-of-charge medicines were non-significant predictors at the bivariate analysis of four or more ANC visits (never entering the multivariate analysis), 54% of health centers mentioned a lack of or insufficient blood pressure monitors, 40% complained about lack of or insufficient adult scales, 34% of stethoscopes, 31% of thermometers, 26% of measuring tapes, 46% of lack of or insufficient HIV/hemoglobin/malaria tests, 54% of lack of at least one medicine from the group of anthelmintics and almost 50% of lack of at least one medicine from the analgesics and antibiotics' groups. Due to the lack of or insufficiency of these materials and medicines, we speculate that, although certainly not associated with the odds of having four or more ANC visits in this study, that a possible association with the quality of the ANC visits or their outcomes may exist.

Sensitivity analysis of uptake of four or more ANC visits

As 25% of the children had missing information on number of ANC visits and a statistically significant difference between background factors of the children/mothers with and without missing information on number of ANC visits was found, a sensitivity analysis was performed. Overall, the results of the sensitivity analysis demonstrate that, despite the slight modification of the magnitude of variation measures, the interpretation of the findings is not substantially altered.

4.3 Uptake of facility birth

The quality of health center's infrastructure was significantly associated with the likelihood of being born at a health facility, as it was regarding the uptake of ANC visits - mothers whose villages were covered by health centers classified as in "bad" conditions by the health professionals had a lower likelihood of giving birth at a health facility compared to mothers whose health center were classified as "reasonable". This occurs in other African settings as well (156, 157). However, lower quality of infrastructure seemed to be more striking regarding delivering at a health facility than attending ANC visits. This may be due to the fact that childbirths occur during the evening, night and early in the morning which is especially sensitive to the existence of electricity. Indeed, in 23% of health centers, responsibles referred to a lack of or an instable source of electricity and in 31% a complete lack of or an insufficient source of clean water at their facilities. Lack of electricity as a major challenge to work at night was also referred to by other African health professionals (158), where resourcing to torches and mobile phones to assist in childbirth was common (159), as it was also reported in the studied regions. A missing or unstable source of water has its implications in the cleaning of surfaces and delivery tables, hand washing of the health professionals and disinfection of cutting delivery equipment, as also observed by other health professionals in the African context (159).

The lack of instruments for delivery was a variable not statistically associated with the odds of delivering in a health facility, possibly as women are not aware of the availability of these items. Still, it is worth noting that 69% of health centers reported missing or insufficient scalpels/clamps/scissors, 49% not having or having insufficient obstetric emergency equipment (e.g., infant and/or maternal mask for resuscitation, aspirator), and 26% missing or insufficient gloves/masks. Issues with the sterilization of materials or surfaces were detected in some visited health centers, due to the lack of (clean) water, sterilization liquids or devices.

Another statically significant predicator of facility birth uptake was the availability of evacuation vehicles and type of vehicle. More specifically, a mother whose village was covered by a health center that owned an ambulance for evacuation was more likely to deliver at a health facility than a mother whose reference health center possessed a motorcycle as an

evacuation vehicle. Availability of an emergency transport during childbirth is an enabler for facility delivery as expressed by east-African women (158, 160) and health professionals alike (159), yet no studies were found that focused on the type of emergency vehicle. It seems reasonable that women who have higher risk perception of intra or inter-partum complications and who deliver at the health facility, would prefer to do it so in a health facility that owns an ambulance, rather than a motorcycle, in case of a need for emergency evacuation. Having the possibility of being transported by an ambulance from home to the health center while in labor, was also regarded as valuable (160). Notwithstanding, only 40% of the health centers visited had an emergency vehicle available, but from these, 71% of the vehicles were ambulances. However, responsibles for the health centers often reported that these ambulances would have mechanical problems, that rendered them unavailable for a period of time.

Distance to health centers was not only a significant predictor of four or more ANC visits but also for facility birth in the studied regions. However, while for ANC visits only distances superior to 8km were associated with this outcome, for facility birth, all categories of distance to health center lower the likelihood of being born at a health facility: 2 to 5km, 5 to 8km and 8km or more away. This difference may be due to the important barrier that is to walk or to be transported 2km or more while in labour. Adding that, the further away the women resided, the more reduced were the odds of her child being born a health facility. This was also verified in other sub-Saharan countries, again coupled with poor road conditions or high travel fares (100, 161) and, for some African women, a long distance to health facility argues in favor of giving birth at home using TBA (156, 162). In fact, in one of the health centers visited in Bafatá, the second closest village to that health center was 7km away, with other village covered by this health center located 35 km away from it. In an attempt to support women that face distance to health facilities as a barrier, “House of mothers” (“casa das mães”), though not a health facility in itself, is a structure existent in the country and located near health facilities, where women that live far way for them or that suffer from obstetric complications during pregnancy, can wait there until the time of delivery (26).

When it comes to children characteristics, the season of the year when they were born is significantly associated with the likelihood of being born at a health facility. However, we found an unexpected direction of association, as children born during the rainy season have higher odds of being born at a health facility than children born during the dry season. Other studies in the African context are not consistent with this observation: studies described that the rate of institutional deliveries is lower during the rainy season than the dry season (163) and how the rainy season is an extreme constraint for women trying to access MCHS, since the heavy rain floods roads and leave them unpassable (157). In addition, a Mozambiquan study explains that it is during the rainy season that women are most involved in agricultural activities and giving birth at home may be more convenient or incur in less indirect costs for the mother (164). Observations from BHP's field data collectors corroborate that the agricultural labor from Bissau-Guinean women is also more intense during the rainy season. A possible explanation for the higher likelihood of facility births during the rainy season in this study, lies with the fact that women perceive a higher risk of delivering outside a health facility during this season (e.g., transportation in case of intra or inter-birth complications) and travel in advance to the health facility to deliver there.

Similar to the ANC uptake, the odds of being born at a health facility reduce about 88% in a higher birth order when compared to the first born, with minimal differences between birth orders. The findings regarding this association were consistent with data from eastern and southern African countries that identified the same association as this study (165). However, another article involving sub-Saharan countries found no association of birth order with uptake of facility births (166). Either way, interpretations found in the literature for a significant association implicate that women at higher birth orders may have felt no difficulties with prior births, or that more children in the household increased the women's responsibility and decreased her time to deliver at a health facility (166, 167). Such explanations, however, are more related to parity (or household size, in this study's case) than birth order. In this study, birth order was a predictor of both facility birth and ANC uptake, but the size of the household showed no statistical significance, and both variables showed no collinearity with each other. This may imply that these variables are distinct, and explanations for (lack) of association between birth order and household size with uptake of

MCHS, can't be confused. On the other hand, Bissau-Guinean children live in an extended family structure, perhaps sharing the same household with other children from possible co-wives or foster children from other families. Raising responsibilities when it comes to children may be shared among co-wives/other family members and thus, be another potential factor influencing the determinant of household size (119).

A positive association between maternal age and the odds of the child being born at a health facility was also identified, similar to the uptake of ANC outcome: women aged between 25 to 35 years and 35 years or more had almost twofold higher odds of giving birth at a health facility when compared with women with less than 19 years (the difference in odds between the two age categories is negligeable). This was also confirmed in other African countries (168). However, other literature from sub-Saharan Africa assessed an inverse association, where the odds of choosing to deliver at a health facility decreased with higher age (161). It seemed that risk perception was also the deciding factor but, in this case, older women, who are usually multiparous, expected fewer obstetric complications than younger women that have less birthing experience (161). Moreover, another study in sub-Saharan Africa that analyzed the effect of maternal age on the place of delivery (169), verified that older age at first birth was associated with higher odds of facility delivery. These contradictory findings may be indicating that parity, specifically being nulliparous or multiparous, could be modifying the effect of maternal age on the probability of facility delivery (and four or more ANC visits) and lead to these conflicting results, as already mentioned previously. As a matter of fact, in this research, the likelihood of being born at a health facility or completing four or more ANC visits reduces with higher birth orders, with this same likelihood increasing with higher maternal age groups. We also highlight that maternal age, from all the predictors significant in Model IV of both ANC and facility birth, is the only one that changes the direction of association between being unadjusted and adjusted to other child and maternal characteristics. This further supports that the effect of maternal age on ANC visits and facility birth uptake may be being modified by household size (parity). For future analyses on the role of women characteristics – namely parity or maternal age – on the use of health services, the study of potential interactions could be relevant.

Lastly, in the studied regions, a previous known facility delivery of older siblings was associated with a higher likelihood of the cohort's child being born at a health facility in comparison with mothers with no history of facility delivery/primigravidae or unknown history of delivery. This association may be due to previous favorable experiences when delivering at a health facility or due to previous complicated deliveries, which encourages the mother to maintain this practice, as highlighted in other African countries (53, 170).

A pre/post-partum room exclusive for women, maternal socioeconomic level, education, ethnicity, previous attendance to at least one ANC consultation, and household size, all showed, individually, no statistically significant association with the odds of the child being born at a health facility. However, in other African countries, maternal education (161), socioeconomic status (161), household size (53), ANC use (53), ethnicity (171) and the health center having a pre/post-partum room exclusive for women (157) were statistically associated with use of health facilities to give birth. These associations were not studied accounting for clustering effect and/or adjusting for upper-level/contextual variables. As previously discussed with ANC use, the potential significant effect of these variables was perhaps not only being captured at a cluster level but, concurrently, being confounded by the other terms included in the models. Nonetheless, these variables may have had an important impact on reducing cluster heterogeneity and explaining some variation in the studied Bissau-Guinean regions. Though the clustering effect was significantly reduced, some between cluster variation is left, being that other predictor variables, especially contextual characteristics, need to be explored still. For instance, TBA over health professionals may still be preferred in Guinea-Bissau (117) and affect the likelihood of a facility delivery. The effectiveness of the CHW in increasing women's uptake of facility birth should also be addressed in future studies (172).

When comparing the independent group-contribution of health center and village geographical characteristics (Model II) against the independent group-contribution of the child and maternal characteristics (Model III), we observe that the upper-level variables conduce to a more impactful decrease of cluster variance in all the three outcomes in Oio, Biombo and Bafatá. Without minimizing the importance of child and maternal variables such

as maternal education or socioeconomic status, we found that contextual factors in Guinea-Bissau exert a stronger influence on the likelihood of a child being fully vaccinated, being born at the health facility, and the mother having had four or more ANC visits. We believe that future studies on this topic must consider associations between determinants of coverage of MCHS and variables that characterize and aggregate villages (considering health center/village geographical resources that villages may or may not be exposed to) in their statistical analysis, to more thoroughly describe the implications of contextual variables (123).

Strengths and limitations

To our knowledge, this is the first study in Guinea-Bissau that not only assessed child and maternal characteristics, health center, and village geographical characteristics but also, using a four-level model, accounted for cluster effect. Some studies conducted in African countries followed similar approaches, with analysis of determinants of uptake and coverage of MCHS in multilevel models accounting for regional differences (99, 104, 111, 145, 146) yet, none was found to include, concomitantly, health center, village geographical, and child and maternal characteristics. As a matter of fact, our study benefited from a robust dataset - HDSS (173), which allowed for an accurate decision regarding the number and complexity of the cluster-levels here analyzed, as well as the inclusion of variables that could only be collected with a sturdy collection system. The large sample size and number of clusters provided more precise results and interpretations.

The HDSS information was further complemented with presential visits to 35 health centers in Biombo, Oio, and Bafatá. With these visits we were able to capture relevant information to explain the contextual factors and provide a more detailed description of the logistic resources that are (not) available at the facilities, informing policy makers of the field shortcomings. In addition, data on the dimension quality of care through the health professional's perspective and characteristics, were also collected and may fundament further research. On that note, all Bafatá and Biombo's health centers were visited, but not all in Oio, as some of them do not have BHP's research currently being conducted at their facilities.

Therefore, we remark that Oio's description as a health region, although comprehensive, is not as thorough as Biombo and Bafatá.

Capturing the effect of women's agency could have also been important in the likelihood of MCHS uptake in the studied regions. Women's agency may derive from maternal education and socioeconomic status (variables here analyzed) (151) and often also from the ethnic/religious/cultural environment that they are part of (115, 174). The family structure that she is involved in or her marriage status (137) , may be decisive in her ability of decision-making (115, 175). The likelihood of the use of MCHS sometimes is also dependent from the level of education of women's partners (145, 176, 177). On the same note, women's perspective of the quality of the care is also missing, as variables that describe quality of care from the perspective of the health professional, although adding some pertaining insights, may be not compatible with the mother's perspective. This perspective is necessary to understand how women view the MCHS and how it could be influencing their uptake.

Some information collected at health centers, namely costs associated with ANC, childhood vaccination and facility birth, lack of material, waiting times, quality of infrastructure and especially job satisfaction, demonstration of dissatisfaction, difficulty in treating women from a different ethnicity and type of difficulty experienced, were all data subjected to socially-desirability bias. However, given the proportion of answers that counteract what can be considered socially desirable, we rely on the truthfulness of the data. Moreover, social desirability in Guinea-Bissau can't be looked at through the same lenses as used in developed countries. For instance, Damerow et al (117), in a qualitative study on the barriers and facilitators to the uptake of MCHS in Guinea-Bissau, reveals how health professionals saw the threat of women who opted for home births with fines as a facilitator for facility births, rather than barriers. Such views were also mentioned during the data collection of this study. It is reasonable to assume that the chronic instability in the health sector, frequent delays in payment of health professionals' salaries, frequent lack of basic working materials, etc. also importantly shape health professionals and women's expectation of what is socially acceptable and not.

The internal and external events described in the beginning of the chapter might have had an effect in both coverage and health centers' predictors assessment. Current and future studies that investigate the extent of the supply and demand-side disruption of MCHS before and after COVID-19, can either confirm the robustness of this study's results or show the magnitude of how MCHS coverages associated with health center, village geographical, and child and maternal predictors were affected. Other factors such as national vaccines stock-outs were particularly severe in 2020-2021 (131) and may have greatly affected childhood vaccination. We recognize the limitations of this outcome – childhood vaccination coverage - and the lower statistical power and advise that these data should be interpreted with caution. Notwithstanding, this is a common indicator for evaluation of MCHS, so it was anticipated that the inclusion of this outcome would provide a broader and more complete picture of the state of these services in the studied regions. In fact, the greater effect of the (non-significant) health center characteristics compared with the child and maternal characteristics in reducing the clustering effect in childhood vaccination coverage, supported this study's observations that contextual variables (regarding health center characteristics and distance to health facility) are primarily more impactful in the likelihood of facility birth, four or more ANC visits and full childhood vaccination coverage.

As for other internal disruptions such as health professional's strikes or political instability, they are frequent events and therefore, this study context, apart from the very long vaccine stock out, is the norm rather than the exception.

With that stated, the three outcomes were calculated with children that were eligible for analysis as early as in 1st of January 2022 and health center data was collected between end of January and mid-April 2023. This required the assumption that health center characteristics (e.g., quality of infrastructure, type of health center, availability of evacuation vehicles and type of vehicle, pre/post-partum room exclusive for women) were consistent throughout time. Other specific health characteristics such as cost of cards, shortages of medicines/materials and waiting times for ANC/vaccination can be perceived, admittedly, as time-period specific. Nevertheless, these variables were included as possible predictors of childhood vaccination, facility births and ANC visits, not necessarily as indicators of the

current shortage of medicines, materials or waiting times, but as indicators of the health sector's ability of planning and managing logistic and human resources. Taking this into account, the proportion of lacking instruments for ANC consultation and for delivery, waiting time for ANC and vaccination, and out-of-stock and free-of-charge ANC medicine, was still cross-examined with reports and, when possible, evidence from 2020-2022 (131). As such, variables that could have reflected past information contrastingly different from current information were excluded (for instance, "out-of-stock vaccines").

The former weaknesses are a result of the cross-sectional design of this study. Other possible flaws derived from this study design are the recall bias. The outcomes ANC and vaccination coverage are reported by the women but also confirmed using the respective cards. Other variables such as socioeconomic indicators are collected already during the registration of pregnancy, therefore a prevailing recall bias is not to expect.

5. Conclusion and Policy recommendations

Progress in maternal and child mortality has been stalling in Guinea-Bissau, where MCHS coverage remains suboptimal (1, 59, 61). This study has found that both supply and demand-side barriers contribute to the uptake of MCHS. The uptake of four or more ANC visits depends on the quality of health centers' infrastructure, the distance to the reference health center, the cost of the reproductive health card, the child's birth order, maternal socioeconomic level, education, age, and ethnicity. For facility births, it does not only depend on the quality of health centers' infrastructure, their distance to the reference health center, maternal age, and birth order, but also on the season of the year, availability of evacuation vehicles, and history of previous facility delivery. Despite none of these variables being significant predictors of full childhood vaccination, a significant amount of heterogeneity, namely at the level of contextual variables, has been observed.

The improvement of MCHS coverage depends, thus, on mitigating both supply- and demand-side barriers. Concerning supply-side barriers, we suggest that governmental institutions and partners continue improving health centers' infrastructures, as this may ensure better physical conditions in healthcare and influence women's perception of care (157, 159). To support women and children that live in villages where distance to health centers is an obstacle, distance can be reduced by assuring that reliable and affordable public transport is available (170, 178) or that appropriate referral transports are in place (179), by building more maternity waiting homes where women can await for the delivery (170, 180), and capacitating health workers with the instruments and vehicles to deliver MCHS during community outreach (74). Continuing to improve the availability of free-of-charge evacuation vehicles, especially ambulances, is also crucial (160). Investment in the quality of roads will not only ensure that these vehicles remain in good condition and mitigate the distance to health facilities but also not exacerbate mothers' poor obstetric health during transportation (159, 160). Importantly, authorities must assure that fees to access to use MCHS, namely costs of reproductive health cards, are eliminated and, from the perspective

of the demand side, that women's socioeconomic level is improved. As maternal education is an underlying factor of socioeconomic status, assuring the conditions for girls and adolescents to attend school will not only influence the mother's economic resources but also increase their exposure, comprehension, and use of health information (140, 141).

This study's findings highlight that several governmental sectors involved in the supply side (e.g., infrastructure, economy, and health ministries) and in the demand side (e.g., education, employment, and women and family ministries) of MCHS have their part in improving coverage of these services in the studied regions. Moreover, our findings also raise the importance of women and child's context, aligned with individual characteristics, in the likelihood of uptake of MCHS. None of these recommendations are simple in their nature or devoid of initial high investments, but necessary long-term solutions to reduce maternal and child mortalities. Finally, the use of multilevel mixed-effect regressions as a methodological approach confirmed that, when assessing determinants of coverage of MCHS in Guinea-Bissau or in other contexts, individual child and maternal variables must be analyzed concurrently with contextual health center and geographical variables, accounting for the cluster heterogeneity of the different levels of analysis.

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7. Supplementary Information

Supplementary information 1.

Description of the implementation of the questionnaires to the health responsibles and the structured interviews to the health professionals

Face-to-face questionnaires were applied to the responsibles of the 35 health centers (one responsible per health center) and the face-to-face structured interviews were conducted with at least two health professionals present at the time of interview. A pilot testing in order to assess the face validity of the questions before starting data collection was performed in two health centers in the capital with eleven health professionals, their suggestions guiding various alterations to the original questionnaires/structured interviews.

In case only one health professional was present, aside the health center responsible, then the responsible would be chosen for the questionnaires but also for the structured interview, to obtain the minimum of two structured interviews per health center. In cases where there were more than two health professionals present, three structured interviews were sought for. Some health centers with greater capacity had more than three health professionals eligible for the structured interviews at the time of visit. In this case, randomization of health professionals was conducted: after listing all the health workers and attributing them a number, three of them were randomly selected trough a Random Numbers Table. However, this was rarely done, since the most visited health centers, the type C facilities, usually did not have more than three health workers on shift.

The questionnaires to the health responsible were composed by a combination of closed questions with pre-categorized answers - for the organizational aspects that could be predicted when the study was designed - and questions where a simple one-word answer was requested (e.g., how much does an infant health card cost? “X” XOF). The structured interviews, as the name implies, sometimes required for the health professionals to give short answers which were then categorized by the researcher after analysis. Portuguese language difficulties are very well known, even among the highest educated people such as health professionals. Therefore, the structured interviews to the health professionals and the questionnaires to the health center responsible were written in portuguese but conducted face-to-face by an experienced field assistant in either Creole or Portuguese, depending on the

language with which the health worker felt most comfortable. At the end, the results were again translated in English. This study's researcher was always also present to ensure quality and consistency of answers. No recording was involved, as the interviewer wrote both the close and the brief open-ended questions. Field notes were registered to aid to interpretation of results. During data collection, interviews to the health responsibles took roughly 30 minutes and to the other health professionals about 10 minutes. Below is the paper version of the questionnaires and structured interviews, and the cue cards.

Questionário ao responsável pelo centro de saúde

Data ____/_____/20___

Centro de saúde :_____	ID Centro de Saúde_____
Tipo de centro de saúde_____	Cargo (enf.-chefe; diretor do CS)_____
Telemóvel:_____	

Código do centro de saúde+ número atribuído ao profissional	**Q1.Função (médico, enfermeiro, parteiro, técnico de farmácia, técnico de laboratório, estagiário, outros)**	**Q2.Sexo (feminino, masculino)**	**Q3.Total de anos em serviço** (número)	**Q4.Etnia (fula, mandinga, balanta, manjaco, mancanha, bijagós, pepel, felupe, beafada, sem etnia, outros, mistura, não sabe, recusa responder)**	**Q5.Em caso de ter turno hoje, se está presente (sim, não)**	**Q6.Dos turnos planeados nos últimos 7 dias, esteve ausente em algum turno (Sim, não); (se sim, motivo: baixa, greve, outros)**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Q7.

Q7.1 Quantos dias da semana o centro de saúde está aberto?_____

Q7.2 Quantos dias da semana, o centro de saúde está aberto só para consultas de emergência, fora do horário normal?_____

Q7.3 A que horas o centro de saúde abre e a que horas é que fecha?_____

Q8.

Q8.1 Em que dias da semana, normalmente, o centro de saúde realiza consultas de cuidado pré-natal?_____

Q8.1.2 A que horas é que as consultas pré-natais começam e a que horas acabam?_____

Q8.2 Em que dias da semana, normalmente, o centro de saúde realiza vacinação para crianças?_____

Q8.2.1 A que horas é que a vacinação para crianças começa e a que horas acaba?_____

Q9.

Q9.1 Nos últimos 7 dias, em média, quanto tempo esperou uma mulher, que veio para uma consulta pré-natal, para ser atendida por um profissional de saúde?_____

Q9.2 Nos últimos 7 dias, em média, quanto tempo esperou uma mulher, que veio para ser assistida no parto, para ser atendida por um profissional de saúde/parteira?_____

Q9.3 Nos últimos 7 dias, em média, quanto tempo esperou uma mulher que veio para a sua criança ser vacinada, para ser atendida por um profissional de saúde? _____

Q10.

Q10.1 Quanto custa, normalmente, para uma mulher que nas gravidezes anteriores deu à luz no seu centro de saúde/ que planeia na primeira gravidez dar à luz no seu centro de saúde:

- uma consulta de cuidado pré-natal?_____

- um cartão de seguimento das grávidas (cartão de prenhada)?_____
- um cartão de vacina do tétano?_____
- uma vacina infantil?_____
- um cartão de vacinação?_____
- a assistência ao parto?_____

Q10.2 Quanto custa, normalmente, para uma mulher que nas gravidezes anteriores deu à luz noutro centro de saúde:

- uma consulta de cuidado pré-natal?_____
- um cartão de seguimento das grávidas (cartão de prenhada)?_____
- um cartão de vacina do tétano?_____
- uma vacina infantil?_____
- um cartão de vacinação?_____
- a assistência ao parto?_____

Q11. No seu centro de saúde, no último mês, foi dado algum apoio material às mulheres/crianças?

☐ Não ☐ Sim.

Q11.1 Qual?

☐ Tenda MILDA criança Q11.2 Quando?_____

☐ Tenda MILDA gestante Quando?_____

☐ Medicamentos Quando?_____

☐ Kit pós parto Quando?_____

☐ Outros Qual?_____ Quando?_____

Q12. Nos últimos 7 dias, notou a rutura de medicamentos ou vacinas de oferta?

(MOSTRAR CARTÃO 1 COM EXEMPLOS DE GRUPOS DE MEDICAMENTOS)

☐ Não houve falta de medicamentos de oferta

☐ Não houve falta de vacinas de oferta

☐ Sim, houve falta de medicamentos de oferta.

Q12.1 Quais?_____

☐ Sim, houve falta de vacinas de oferta.

Q12.2 Quais?_____

☐ Não sabe

Q13. Nos últimos 7 dias, notou a rutura de medicamentos ou vacinas que não são de oferta?

(MOSTRAR CARTÃO 1 COM EXEMPLOS DE GRUPOS DE MEDICAMENTOS)

☐ Não houve falta de medicamentos que não são de oferta

☐ Não houve falta de vacinas que não são de oferta

☐ Sim, houve falta de medicamentos que não são de oferta.

Q13.1 Quais?_____

☐ Sim, houve falta de vacinas que não são de oferta.

Q13.2 Quais?_____

☐ Não sabe

Q14. Nos últimos 7 dias, notou a falta de instrumentos de trabalho que são absolutamente necessários para tratar pessoas?

(MOSTRAR CARTÃO 2 COM EXEMPLOS DE INSTRUMENTOS DE TRABALHO)

☐ Não houve falta de instrumentos absolutamente necessários para prestar cuidados

☐ Sim, houve falta de instrumentos absolutamente necessários para prestar cuidados.

Q14.1Quais?

_____

Q15. O seu centro de saúde possui algum veículo para transporte de pacientes?

☐ Não ☐ Sim. Q15.1 Quantos? _____

Q15.2 Qual?_____

Qual?_____

Q15.3 Se sim, quanto custa, em média, um transporte para um hospital principal?_____

Q15.4 Se sim, é um profissional de saúde (por exemplo, médico, enfermeiro) que está de turno que conduz o transporte?

☐ Não ☐ Sim

Q16. O seu centro de saúde fornece exames complementares de diagnóstico de oferta ou pagos?
(MOSTRAR CARTÃO 3 COM LISTA DE EXAMES COMPLEMENTARES DE DIAGNÓSTICO)

☐ Não, não fornece exames complementares de diagnóstico de oferta

☐ Não, não fornece exames complementares de diagnóstico pagos

☐ Sim, fornece exames complementares de diagnóstico de oferta

☐ Sim, fornece exames complementares de diagnóstico pagos

☐ Não sabe

Q17. De forma geral, como avalia a infraestrutura do centro de saúde, tendo em conta saneamento, eletricidade, higiene?
(MOSTRAR CARTÃO 4 COM RESPOSTAS ACERCA DA QUALIDADE)

☐ 1 Muito má ☐ 2 Má ☐ 3 Razoável ☐ 4 Boa ☐ 5 Muito boa ☐ 6 Não sabe ☐ 7 Recusa responder

Q.17.1 O seu centro de saúde possui uma sala de partos?

☐ Não ☐ Sim

Q17.2 O centro de saúde possui uma sala pré-parto ou pós parto onde só podem estar as mulheres em trabalho de parto e não outros pacientes masculinos?

☐ Não ☐ Sim

Q18. No último mês, no centro de saúde, existiram formações teórico-prática oferecidas aos profissionais, seja no centro de saúde ou em outro local externo?

☐ Não ☐ Sim

Q18.1 Se existiram, qual foi o tema das formações?

☐ Prevenção e controlo de infeção
☐ Emergência obstétrica
☐ controlo de resíduos hospitalares
☐ consulta de pré natal
☐ consulta infantil
☐ Outros. Quais?_____

Entrevista estruturada ao profissional de saúde

Data ____/_____/20___

Centro de saúde :_____ ID Centro de Saúde_____

Tipo de centro de saúde_____ ~

Código (Código do centro de saúde+ número atribuído ao profissional) Ex: 10202 _____

Q1. De forma geral, como avalia a infraestrutura do centro de saúde, tendo em conta saneamento, eletricidade, higiene?

(MOSTRAR CARTÃO 4 COM RESPOSTAS ACERCA DA QUALIDADE)

☐ 1 Muito má ☐ 2 Má ☐ 3 Razoável ☐ 4 Boa ☐ 5 Muito boa ☐ 6 Não sabe
☐ 7 Recusa responder

Q2. Que serviços costuma dar às mulheres/crianças?

☐ Consultas pré-natal ☐ Assistência no parto ☐ Vacinação nas crianças

Q2.1 No último mês, com que frequência durante os serviços que costuma dar, explicou à mulher o que estava a fazer a ela ou à sua criança? **(dar como exemplo se a pessoa não entender: Explica que vai medir o fundo uterino; explica qual é a vacina que está a dar; explica que vai ter que medir a largura do colo do útero, em caso de parto)**

(MOSTRAR CARTÃO 5 COM RESPOSTAS DE FREQUÊNCIA)

☐ 1 Nunca ☐ 2 Raramente ☐ 3 Às vezes ☐ 4 Quase sempre ☐ 5 Sempre
☐ 6 Não sabe ☐ 7 Recusa responder

Q3. No último mês, com que frequência se sentiu descontente com o seu trabalho no centro de saúde?
(MOSTRAR CARTÃO 5 COM RESPOSTAS DE FREQUÊNCIA)
☐ 1 Nunca ☐ 2 Raramente ☐ 3 Às vezes ☐ 4 Quase sempre ☐ 5 Sempre
☐ 6 Não sabe ☐ 7 Recusa responder

Q3.1 (Se respondeu às **vezes, quase sempre ou sempre na questão Q.3)**, **como mostra** o seu descontentamento aos seus colegas ou pacientes? **(dar como exemplo se a pessoa não entender: não vem trabalhar, grita com os pacientes, não tem paciência com os colegas)**

_____

_____

_____

Q3.2**.** (Se respondeu **às vezes, quase sempre ou sempre na questão Q.3)** com que **frequência** acha que os seus colegas ou pacientes notam o seu descontentamento?
(MOSTRAR CARTÃO 5 COM RESPOSTAS DE FREQUÊNCIA

☐ 1 Nunca ☐ 2 Raramente ☐ 3 Às vezes ☐ 4 Quase sempre ☐ 5 Sempre
☐ 6 Não sabe ☐ 7 Recusa responder

Q4. Caso não fale a mesma língua que a mulher/criança, como faz para comunicar com ela? (**dar como exemplo se a pessoa não entender: não comunica, procura outro colega para traduzir, procura outro paciente para traduzir, procura um familiar para traduzir)**

_____

Q5. Durante o seu trabalho, sente que tem dificuldades em tratar mulheres/crianças de uma etnia diferente da sua? **(dar como exemplo: não perde muito tempo, é antipático, cobra pelo serviço gratuito)**

☐ Não ☐ Sim

Q5.1 **(Se respondeu sim na questão Q.5)**, na sua opinião, de que modo é tem dificuldades em tratar de mulheres/crianças de etnia diferente da sua?

_____

_____

Q5.2 **(Se respondeu sim na questão Q.5) com** qual etnia é que sente mais dificuldade?

☐ Fula ☐ Balanta ☐ Pepel ☐ 4 Manjaco ☐ Mancanha ☐ Mandinga ☐ Beafada ☐ Felupe ☐ Bijagós ☐ Outra ☐ Recusa responder

Cartão 1 Lista de grupos medicamentos essenciais

1. Anestéticos
2. Analgésicos
3. Anti-inflamatórios
4. Anti-alérgicos
5. Anti-convulsionantes
6. Antihelmíticos
7. Antibióticos
8. Antischitosomais
9. Anti tuberculose
10. Antifúngicos
11. Antivirais
12. Antimaláricos
13. Antifilarials (albendazole, ivermectin)
14. Anti-hipertensores
15. Medicamentos que afetam o sangue
16. Sangue e derivados
17. Medicamentos cardiovasculares
18. Diuréticos
19. Desinfetantes
20. Medicamentos gastrointestinais
21. Medicamentos para distúrbios endócrinos
22. Medicamentos para saúde reprodutiva e perinatal
23. Medicamentos para desordens mentais
24. Medicamentos para desordens do trato respiratório
25. Soluções para correção eletrolítica e distúrbios ácido-base
26. Vitaminas e minerais
27. Medicamentos reumáticos
28. vacina BCG
29. vacina pentavalente (difteria, tétano, pertússis, hepatite B, haemophilus influenza tipo b)
30. vacina contra sarampo
31. vacina pneumocócica
32. vacina poliomielite
33. vacina rotavirus
34. vacina rubéola
35. vacina antitetânica
36. vacina febre-amarela

Cartão 2 Lista de instrumentos de trabalho essenciais

1. Balança
2. Estetoscópio
3. Termómetro
4. Cartão de vacinação de criança
5. Cartão de mulher em idade fértil
6. Aparelho para medir tensão
7. Fita métrica para medir altura uterina
8. Balança para criança
9. Luvas, toucas, máscara, uniforme
10. Lâmina/tesoura/pinça para cortar cordão umbilical
11. Teste de HIV/malária/hemoglobina/urina/fezes
12. Equipamento de emergência
13. Equipamento de emergência obstétrica
14. Frigorífico
15. Congelador
16. Água
17. Eletricidade

Cartão 3 Lista de exames complementares de diagnóstico

1. Teste de urina tipo I e II
2. Teste de fezes
3. Teste de hemoglobina, grupo sanguíneo
4. Teste de VIH, malária
5. Testes de deteção de IST (sífilis, clamídia, hepatite B)
6. Teste de glicemia
7. Teste de gravidez
8. Ecografia

Cartão 4 Respostas relativas à qualidade da infraestrutura do centro de saúde

MUITO MÁ

MÁ

RAZOÁVEL

BOA

MUITO BOA

NÃO SABE

RECUSA RESPONDER

Cartão 5 Respostas relativas à frequência

MUITO MÁ

MÁ

RAZOÁVEL

BOA

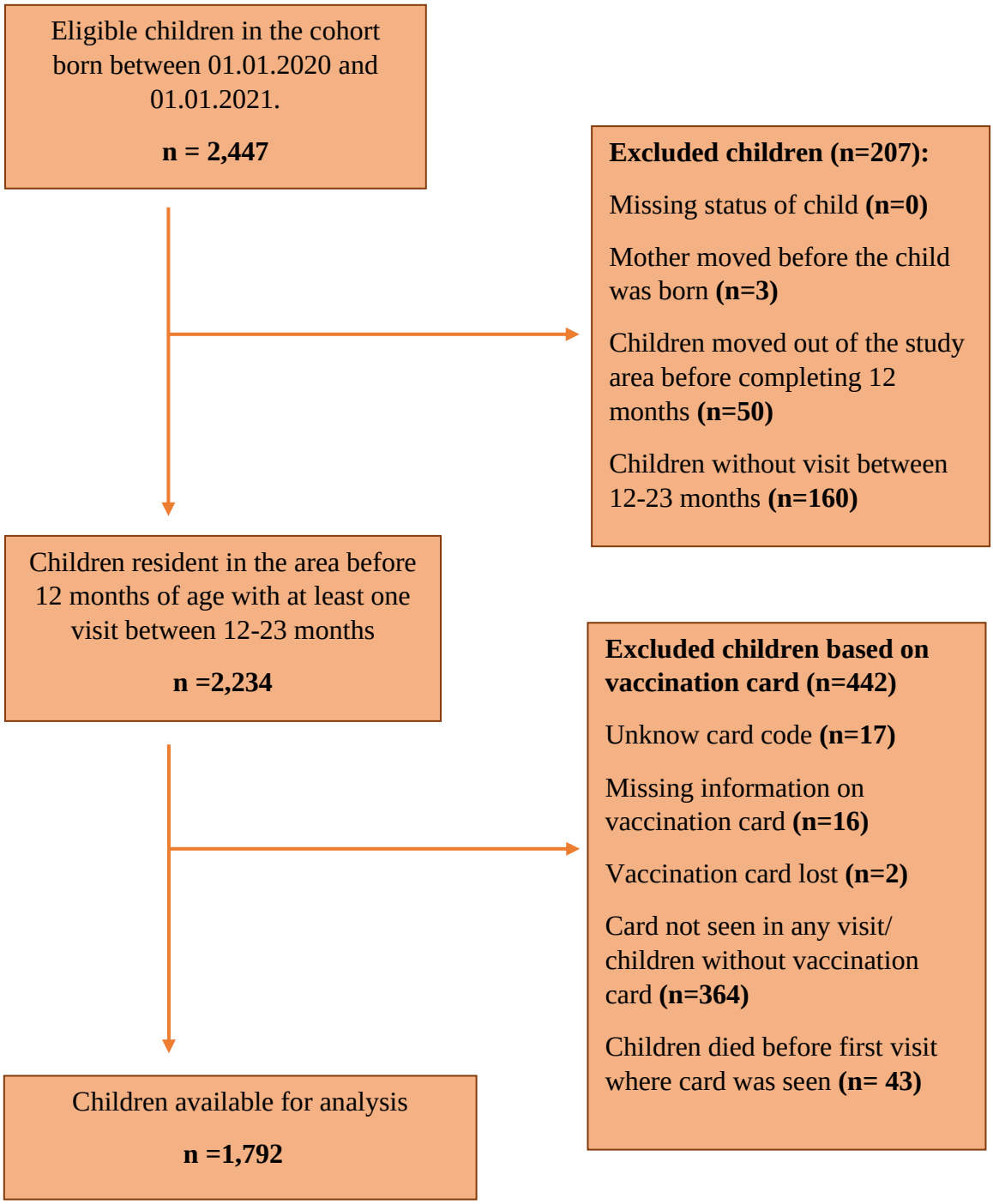
MUITO BOA

NÃO SABE

RECUSA RESPONDER

Supplementary information 2.

Flowchart of available children for analysis for the outcome childhood vaccination coverage



Supplementary information 3.

Estimation of women's socioeconomic level

Measuring wealth status in the rural Bissau-Guinean setting requests a study in itself. Until then, assessing if the woman possesses certain household items is the best available tool for estimating socioeconomic level. Recognizing the limited interpretation of this tool, below we explain how the five levels of the Socioeconomic level were calculated.

From the HDSS household wealth variables - **possession of mobile phone, radio, generator/solar panel, toilet (outdoor) and type of roof (hard) -** a score of 1 to each household variable was attributed if the mother possessed these household items and 0 if she had not; then the sum of the score of all the variables was conducted and the total was then categorized in 4 socioeconomic levels. The highest score - level 5 - represents a woman with all the mentioned household items (and thus 1 in each of the variables) and therefore the highest socioeconomic level; the lowest scores - level 0 to 2 - represent a woman with none or almost none of these household items, and therefore the lowest socioeconomic levels (see Table below).

A woman whose at least one of the household items' information is missing, is classified as having a missing socioeconomic level.

Mother ID	Radio	Toilet*	Roof *	Mobile phone	Generator	Score	Socioeconomic index level
999999	Yes [1]	Outdoor [1]	Zinc/metal [1]	Yes [1]	Yes [1]	5	Level 5
888888	Yes [1]	Outdoor [1]	Zinc/metal [1]	No [0]	Yes [1]	4	Level 4
777777	No [0]	Outdoor [1]	Zinc/metal [1]	Yes [1]	No [0]	3	Level 3
666666	Yes [1]	Indoor [0]	Straw [0]	Yes [1]	No [0]	2	Level 0-2
555555	No [0]	Indoor [0]	Straw [0]	Yes [1]	No [0]	1	Level 0-2
444444	No [0]	Indoor [0]	Straw [0]	No [0]	No [0]	0	Level 0-2
333333	No [0]	Outdoor [1]	Zinc/metal [1]	No [0]	Missing	Missing	Missing
222222	Missing	Missing	Zinc/metal [1]	No [0]	Yes [1]	Missing	Missing

Note: *Toilet is coded as indoor (0) and outdoor (1); Roof is coded as straw (0) and zinc/metal (1)

Supplementary information 4.

Health professional socio-demographic characteristics

Part a) 240 health professionals from 35 visited health centers

Socio-demographic characteristics of all health professionals	Region			
	Bafatá	Biombo	Oio	Total
Total sample	Frequency *(%)*	Frequency *(%)*	Frequency *(%)*	Frequency *(%)*
	104 (43)	**71 (30)**	**65 (27)**	**240 (100)**
IQR 10 (5-15) *				
Sex				
Male	43 (41)	28 (39)	28 (43)	99 (41)
Female	61 (43)	43 (61)	37 (57)	141 (59)
Years on service (years)				
<5	70 (67)	15 (21)	33 (51)	118 (49)
>=5 to 10	13 (13)	29 (41)	21 (32)	63 (26)
>=10 to 20	16 (15)	15 (21)	7 (11)	38 (16)
>=20	5 (5)	12 (17)	4 (6)	21 (9)
Ethnicity				
Balanta	21 (20)	11 (16)	14 (22)	46 (19)
Pepel	13 (13)	14 (20)	10 (15)	37 (15)
Mancanha	16 (15)	10 (14)	6 (9)	32 (13)
Fula	17 (16)	6 (9)	5 (8)	28 (12)
Manjaco	12 (12)	8 (11)	7 (11)	27 (11)
Mandinga	6 (6)	2 (3)	7 (11)	15 (6)
Bijagós	4 (4)	5 (7)	3 (5)	12 (5)
Beafada	4 (4)	2 (3)	4 (6)	10 (4)
Felupe	2 (2)	0	2 (3)	4 (2)
Multi-ethnic	1 (1)	10 (14)	4 (6)	15 (6)
Others	6 (6)	2 (3)	3 (5)	11 (5)
Unknown	2 (2)	1 (1)	0	3 (1)
Cadre				
Nurse	59 (57)	43 (61)	50 (77)	152 (63)
Midwife	28 (27)	7 (10)	8 (12)	43 (18)
Physician	7 (7)	3 (4)	2 (3)	12 (5)
Laboratory technician/ Pharmacy technician	8 (8)	8 (11)	2 (3)	18 (8)
Others	2 (1)	10 (14)	3 (5)	15 (6)

Notes: The IQR refers to the median of health professionals per health center

Supplementary information 5.

Bivariate multilevel mixed effect logistic regression analyses for uptake of childhood vaccination

(A) Health center, (B) village geographical, and (C) child and maternal characteristics

Uptake of full childhood vaccination (*n*=29 health centers)	Total (*n*=1,739 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	Not fully vaccinated 804 (46)	Fully vaccinated 953 (54)	
Health center characteristics			
Type of Health Center			
B	126 (16)	79 (8)	1
C	678 (84)	856 (92)	**2.28 (1.40, 3.71)**
Children vaccination (nº of days/week)			
5	766 (95)	885 (95)	1
7	38 (5)	50 (5)	1.14 (0.59, 2.21)
Waiting time for children vaccination (hours)			
<2	366 (46)	494 (53)	1
>= 2	438 (54)	441 (47)	0.95 (0.66, 1.37)
Infant Health Card cost			
No cost	609 (76)	732 (78)	1
Fixed cost	153 (19)	171 (18)	0.71 (0.45, 1.12)
Unfixed/unknown cost	42 (5)	32 (3)	0.54 (0.27, 1.08)
Quality of infrastructure			
Reasonable	385 (48)	346 (37)	1
Good	397 (49)	556 (59)	**1.68 (1.18, 2.38)**
Bad	22 (3)	33 (4)	1.91 (0.79, 4.62)
Distribution of Mosquito Net (at 1º vaccine)			
Yes	683 (85)	777 (83)	1
No	121 (15)	158 (17)	1.09(0.71, 1.69)

(A) Notes * uOR = unadjusted Odds Ratio accounted for Family group, Village and Sanitary Area with 80%CI = 80% Confidence Interval. For uOR, *p* value was set at < 0.2.

Uptake of full childhood vaccination (*n*=29 health centers)	Total (*n*=1,739 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	Not fully vaccinated 804 (46)	Fully vaccinated 953 (54)	
Village geographical characteristics			
Distance to health center			
< 2km	122 (15)	110 (12)	1
>=2 to 5km	131 (17)	190 (21)	1.33 (0.89, 2.00)
>=5 to 8km	155 (20)	207 (23)	1.14 (0.76, 1.71)
>=8km	386 (49)	411 (45)	1.09 (0.75, 1.58)

(B) **Notes:** Missing observations: Distance to health center (27)

Uptake of full childhood vaccination (*n*=29 health centers)	Total (*n*=1,739 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	Not fully vaccinated 804 (46)	Fully vaccinated 953 (54)	
Child socio-demographic characteristics			
Sex			
Male	400 (50)	485 (52)	1
Female	404 (50)	449 (48)	0.97 (0.84, 1.12)
Place of birth			
Health facility	342 (46)	440 (50)	1
Home/Other	405 (54)	434 (50)	0.87 (0.74, 1.03)
Birth order			
1st	141 (18)	167 (18)	1
2nd or 3rd	293 (37)	328 (35)	0.95 (0.77, 1.17)
4th or 5th	195 (24)	239 (26)	0.99 (0.79, 1.23)
>=6th	172 (21)	191 (20)	0.97 (0.77, 1.23)
Maternal socioeconomic, socio-demographic, and obstetric characteristics			
Socioeconomic level			
Level 0-2	98 (13)	97 (11)	1
Level 3	130 (17)	162 (18)	1.29 (0.97, 1.72)
Level 4	264 (35)	340 (38)	1.24 (0.95, 1.62)
Level 5	257 (34)	292 (33)	1.02 (0.77, 1.34)
Education (years)			
No formal education	412 (53)	494 (54)	1
>=1 to 4	149 (19)	156 (17)	0.83 (0.67, 1.02)
>=4 to 6	126 (16)	146 (16)	0.99 (0.79, 1.23)
>=6	96 (12)	123 (13)	1.22 (0.95, 1.56)
Age (years)			
< 19	82 (10)	97 (11)	1
>=19 to 25	284 (36)	319 (35)	0.99 (0.77, 1.29)
>=25 to 35	320 (40)	412 (45)	1.15 (0.89, 1.48)
>=35	108 (14)	92 (10)	**0.71 (0.52, 0.98)**
Ethnicity			
Fula	316 (45)	410 (47)	1
Mandinga	229 (29)	258 (28)	0.97 (0.72, 1.30)
Balanta	138 (17)	142 (15)	0.71 (0.48, 1.05)
Pepel	97 (12)	97 (10)	0.71 (0.44,1.14)
Manjaco/Mancanha	8 (1)	11 (1)	1.07 (0.47, 2.41)
Other/Multi-ethnic	11 (2)	14 (2)	1.02 (0.53, 1.95)
Mother attended at least one ANC consultation			
Yes	717 (96)	851 (97)	1
No / Doesn't know	31 (4)	27 (3)	0.83 (0.55, 1.26)
Household size			
< 3 children	492 (61)	576 (62)	1
>=3 to 6 children	252 (31)	318 (34)	1.05 (0.89, 1.23)
>= 6 children	58 (7)	40 (4)	**0.55 (0.40, 0.76)**

(C) Notes: Missing observations: Sex (1), Place of birth (118), Birth order (13), Socioeconomic level (99), Ethnicity (8), Age (25), Education (26), Mother attended at least one ANC consultation (113), Household size (3)

Bivariate multilevel mixed effects logistic regression analyses for ANC coverage

(A) Health center, (B) child and maternal, and (C) village geographical characteristics

Uptake of four or more ANC visits (*n*=29 health centers)	Total (*n*=3,419 children)		Unadjusted OR (80% CI)
	Frequency *(%)*		
Total sample	< 4 ANC visits 2,015 (59)	>=4 ANC visits 1,404 (41)	
Health center characteristics			
Type of Health Center			
B	264 (13)	205 (15)	1
C	1,751 (87)	1,199 (85)	0.96 (0.59, 1.58)
Emergency care (days/week)			
0	392 (19)	251 (18)	1
7	1,623 (81)	1,153 (82)	1.35 (0.75, 2.44)
Waiting time for ANC consultation (hours)			
< 2	802 (40)	546 (39)	1
>= 2	1,213 (60)	858 (61)	1.21 (0.85, 1.73)
ANC consultations (nº of days/week)			
5	1,848 (91)	1,326 (94)	1
7	117 (8)	78 (6)	**0.50 (0.28, 0.88)**
Reproductive Health Card cost			
No cost	1,305 (65)	853 (61)	1
Fixed cost	635 (32)	456 (32)	0.87 (0.58, 1.31)
Unfixed/unknow cost	75 (4)	95 (7)	**1.98 (1.04, 3.78)**
Quality of infrastructure			
Reasonable	928 (46)	579 (41)	1
Good	1,012 (50)	809 (58)	1.17 (0.84, 1.62)
Bad	75 (4)	16 (1)	**0.25 (0.10, 0.60)**
Evacuation vehicles and type of vehicle			
No	1,223 (61)	880 (63)	1
Yes, ambulance	662 (33)	466 (33)	1.14 (0.79, 1.64)
Yes, motorcycle	130 (7)	58 (4)	**0.52 (0.27, 0.99)**
Health center performs ultrasound			
Yes	309 (15)	234 (17)	1
No	1,706 (85)	1,170 (83)	0.88 (0.46, 1.68)
Lack of instruments for ANC consultation ♠			
Yes	1,974 (98)	1,382 (98)	1
No	41 (2)	22 (2)	0.84 (0.25, 2.87)
Out-of-stock and free-of-charge ANC medicine▲			
Yes	1,653 (82)	1,201 (86)	1
No	362 (18)	203 (14)	0.76 (0.49, 1.18)
Distribution of Mosquito Net (at 1º ANC)			
Yes	1,799 (89)	1,274 (91)	1
No	216 (11)	130 (9)	0.97 (0.61, 1.53)

(A) Notes * uOR = unadjusted Odds Ratio accounted for Family group, Village and Sanitary Area with 80%CI = 80% Confidence Interval. For uOR, *p* value was set at < 0.2. ♠ Lack of instruments for ANC consultation (lack of at least one of the listed instruments): Stethoscope, Blood pressure monitor, Measure tape, HIV/malaria tests, Scale, Reproductive Health Card ▲ Out-of-stock and free-of-charge medicine (at least one group missing at HC): Analgesics, Antimalarials, Antiretrovirals, Anthelmintics, Antibiotics

Uptake of four or more ANC visits (*n*=29 health centers)	Total (*n*=3,419 children)		Unadjusted OR (80% CI)
	Frequency *(%)*		
Total sample	< 4 ANC visits 2,015 (59)	>=4 ANC visits 1,404 (41)	
Child socio-demographic characteristics			
Sex			
Male	1,011 (50)	715 (51)	1
Female	1,004 (50	688 (49)	0.94 (0.85, 1.04)
Birth order			
1st	310 (15)	291 (21)	1
2nd or 3rd	659 (33)	473 (34)	**0.66 (0.56, 0.77)**
4th or 5th	544 (27)	359 (26)	**0.62 (0.52, 0.73)**
>=6th	493 (25)	274 (20)	**0.51 (0.43, 0.60)**
Maternal socioeconomic, socio-demographic, and obstetric characteristics			
Socioeconomic level			
Level 0-2	159 (8)	78 (6)	1
Level 3	325 (17)	173 (13)	1.01 (0.84, 1.39)
Level 4	654 (34)	457 (34)	**1.41 (1.12, 1.78)**
Level 5	777 (41)	646 (48)	**1.67 (1.32, 2.12)**
Education (years)			
No formal education	1,059 (54)	624 (45)	1
>=1 to 4	380 (19)	284 (21)	**1.21 (1.05, 1.40)**
>=4 to 6	299 (15)	255 (18)	**1.55 (1.33, 1.81)**
>=6	235 (12)	216 (16)	**1.62 (1.36, 1.93)**
Age (years)			
<19	204 (10)	153 (11)	1
>=19 to 25	689 (35)	445 (32)	**0.81 (0.68, 0.98)**
>=25 to 35	842 (42)	618 (45)	0.85 (0.71, 1.02)
>=35	261 (13)	169 (12)	**0.80 (0.64, 1.00)**
Ethnicity			
Fula	675 (34)	607 (44)	1
Mandinga	631 (31)	343 (25)	0.87 (0.68, 1.11)
Balanta	415 (21)	161 (12)	**0.60 (0.44, 0.84)**
Pepel	239 (12)	248 (18)	1.40 (0.97, 2.02)
Manjaco/Mancanha	10 (1)	16 (1)	1.67 (0.87, 3.21)
Other/Multi-ethnic	36 (2)	18 (1)	0.63 (0.39, 1.02)
Known history of stillbirth			
Yes	132 (7)	101 (7)	1
No / Primigravidae	1,879 (93)	1,301 (93)	0.96 (0.71, 1.18)
Household size			
< 3 children	1,134 (56)	850 (61)	1
>=3 to 6 children	736 (37)	479 (34)	**0.83 (0.75, 0.93)**
>= 6 children	143 (7)	74 (5)	**0.63 (0.51, 0.79)**

(B) Notes: Missing observations: Sex (1), Place of birth (118), Birth order (13), Socioeconomic level (99), Ethnicity (8), Age (25), Education (26), Distance to health center (27), Mother attended at least one ANC consultation (113), Household size (3)

Uptake of four or more ANC visits (*n*=29 health centers)	Total (*n*=3,419 children)		Unadjusted OR (80% CI)
	Frequency *(%)*		
Total sample	**< 4 ANC visits 2,015 (59)**	**>=4 ANC visits 1,404 (41)**	
Village geographical characteristics			
Distance to health center			
< 2km	244 (13)	235 (17)	1
>=2 to 5km	346 (17)	248 (18)	**0.56 (0.40, 0.79)**
>=5 to 8km	444 (22)	319 (23)	**0.62 (0.44, 0.87)**
>=8km	956 (48)	581 (42)	**0.49 (0.35, 0.68)**

(C) Notes: Missing observations: distance to health center (27)

Bivariate multilevel mixed effect logistic regression analyses for facility birth coverage

(A) Health center, (B) village geographical, and (C) child and maternal characteristics

Uptake of facility birth (*n*=27 health centers)	Total (*n*= 3,682 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	No facility birth 1,908 (52)	Facility birth 1,774 (48)	
Health center characteristics			
Type of Health Center			
B	268 (14)	371 (21)	1
C	1,640 (86)	1,403 (79)	0.69 (0.43, 1.12)
Lack of instruments for delivery ┼			
Yes	1,531 (80)	1,431 (81)	1
No	377 (20)	343 (19)	0.91 (0.57, 1.43)
Pre/post-partum room exclusive for women			
Yes	1,490 (78)	1,499 (85)	1
No	418 (22)	275 (16)	**0.57 (0.35, 0.92)**
Evacuation vehicles and type of vehicle			
Yes, ambulance	632 (33)	839 (47)	1
Yes, motorcycle	193 (10)	68 (4)	**0.16 (0.09, 0.30)**
No vehicle	1,083 (67)	867 (49)	**0.54 (0.40,0.73)**
Quality of infrastructure			
Reasonable	988 (52)	1,019 (57)	1
Good	804 (42)	718 (40)	0.92 (0.66, 1.29)
Bad	116 (6)	37 (2)	**0.29 (0.13, 0.64)**
Health center performs ultrasound			
Yes	38 (2)	93 (5)	1
No	1,870 (98)	1,681 (95)	0.45 (0.15, 1.32)

(A) Notes * uOR = unadjusted Odds Ratio accounted for Family group, Village and Sanitary Area with 80%CI = 80% Confidence Interval. For uOR, *p* value was set at < 0.2; ┼ Lack of instruments for delivery (lack of at least one group): Gloves/Cap/Masks, Scissors/Clamp/Scalpel, Emergency equipment

Uptake of facility birth (*n*=27 health centers)	Total (*n*= 3,682 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	No facility birth 1,908 (52)	Facility birth 1,774 (48)	
Village geographical characteristics			
Distance to health center			
< 2km	174 (9)	423 (24)	1
>=2 to 5km	330 (17)	369 (21)	**0.42 (0.29, 0.63)**
>=5 to 8km	591 (31)	436 (24)	**0.34 (0.23, 0.50)**
>=8km	804 (42)	524 (30)	**0.23 (0.16, 0.34)**

(B) Notes: Missing observations: distance to health center (31)

Uptake of facility birth (*n*=27 health centers)	Total (*n*= 3,682 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	No facility birth 1,908 (52)	Facility birth 1,774 (48)	
Child socio-demographic characteristics			
Sex			
Male	949 (50)	896 (51)	1
Female	956 (50)	875 (49)	0.92 (0.83, 1.01)
Season of the year (at birth)			
Dry season	1,199 (63)	1,009 (57)	1
Rainy season	709 (37)	765 (43)	**1.28 (1.16, 1.43)**
Birth order			
1st	203 (11)	471 (27)	1
2nd or 3rd	678 (36)	563 (32)	**0.25 (0.21, 0.30)**
4th or 5th	3562 (30)	372 (21)	**0.21 (0.18, 0.25)**
>=6th	459 (24)	359 (20)	**0.26 (0.22, 0.32)**
Maternal socioeconomic, socio-demographic, and obstetric characteristics			
Socioeconomic level			
Level 0-2	171 (9)	138 (8)	1
Level 3	334 (18)	269 (16)	0.92 (0.74,1.15)
Level 4	614 (34)	571 (34)	1.14 (0.93, 1.40)
Level 5	694 (38)	718 (42)	**1.34 (1.08, 1.65)**
Education (years)			
No formal education	1,019 (55)	777 (44)	1
>=1 to 4	366 (20)	340 (19)	1.05 (0.91, 1.21)
>=4 to 6	288 (15)	339 (19)	**1.32 (1.13, 1.53)**
>=6	190 (10)	295 (17)	**1.63 (1.37, 1.95)**
Age (years)			
<19	167 (9)	259 (15)	1
>=19 to 25	631 (33)	582 (33)	**0.48 (0.40,0.58)**
>=25 to 35	832 (44)	708 (40)	**0.42 (0.36, 0.51)**
>=35	254 (13)	204 (12)	**0.40 (0.33, 0.50)**
Ethnicity			
Fula	678 (36)	655 (37)	1
Mandinga	533 (28)	408 (23)	1.09 (0.84, 1.41)
Balanta	457 (24)	202 (11)	**0.70 (0.52, 0.94)**
Pepel	212 (11)	202 (11)	**2.43 (1.76, 3.37)**
Manjaco/Mancanha	5 (0)	452 (26)	**2.37 (1.05, 5.33)**
Other/Multi-ethnic	16 (1)	32 (2)	1.66 (0.99, 2.78)

Uptake of facility birth (*n*=27 health centers)	Total (*n*= 3,682 children)		Unadjusted OR (80% CI) * (continuation)
	Frequency *(%)*		
Total sample	No facility birth 1,908 (52)	Facility birth 1,774 (48)	
Known history of stillbirth			
Yes	124 (7)	128 (7)	1
No / Primigravidae	1,782 (93)	1,643 (93)	0.87 (0.71, 1.07)
Household size			
< 3 children	1,053 (55)	1,154 (65)	1
>=3 to 6 children	726 (38)	508 (29)	**0.60 (0.53, 0.67)**
>= 6 children	127 (7)	111 (6)	**0.78 (0.63, 0.96)**
Mother attended at least one ANC consultation			
Yes	1,778 (94)	1,686 (96)	1
No / Doesn't know	113 (6)	71 (4)	**0.75 (0.59, 0.95)**
Mother has a pregnancy card at first visit after birth			
Yes	1,566 (91)	1,373 (92)	1
No / Doesn't know	161 (9)	121 (8)	0.98 (0.80, 1.19)
Known history of facility delivery			
Yes	570 (30)	718 (40)	1
No / Primigravidae	364 (19)	413 (23)	**1.28 (1.11, 1.48)**
Unknow	974 (51)	643 (36)	**0.67 (0.59, 0.75)**

(C) Notes: Missing observations: Sex (6), Birth order (15), Socioeconomic level (173), Ethnicity (15), Age (45), Education (51), Mother attended at least one ANC consultation (34) Known history of stillbirth (4), Household size (3)

Supplementary information 6.

Sensitivity analysis of coverage of ANC visits

Chi-square test of independence between the background factors of women/child with and without missing information on number of ANC visits

Uptake of ANC visits	Background factors between women/children with and without missing information on number of ANC visits		*p* value χ^2
	Frequency *(%)*		
	Without missing information on ANC visits	With missing information on ANC visits	
Total sample	3,419 (75)	1,137 (25)	**Total (*n*=4,556)**
Health center characteristics			
Type of healthcenter			
B	469 (73)	175 (27)	0.160
C	2,950 (75)	962 (25)	
Emergency care (days/week)			
0	643 (75)	210 (25)	0.801
7	2,776 (75)	927 (25)	
Waiting time for ANC consultation (hours)			
<2	1,348 (72)	516 (28)	**< 0.001**
>= 2	2,071 (77)	621 (23)	
ANC consultations (nº of days/week)			
5	3,174 (75)	1,044 (25)	0.259
7	245 (72)	93 (28)	
Reproductive Health Card cost			
No cost	2,158 (74)	744 (26)	0.345
Fixed cost	1,091 (76)	337 (24)	
Unfixed/unknown cost	170 (75)	56 (25)	
Lack of instruments for ANC consultation			
Yes	3,356 (75)	1,123 (25)	0.166
No	63 (82)	14 (18)	
Out-of-stock and free-of-charge ANC medicine			
Yes	2,854 (76)	906 (24)	**0.004**
No	565 (71)	231 (29)	
Health center performs ultrasound			
Yes	543 (77)	160 (23)	0.143
No	2,876 (75)	977 (25)	
Quality of infrastructure			
Reasonable	1,507 (75)	511 (25)	**< 0.001**
Good	1,821 (76)	562 (24)	
Bad	91 (59)	64 (41)	
Distribution of Mosquito Net (at 1º ANC)			
Yes	3,073 (76)	961 (24)	**< 0.001**
No	346 (66)	176 (34)	

Evacuation vehicles and type of vehicle			
No	2,103 (75)	708 (25)	0.208
Yes, ambulance	1,128 (76)	353 (24)	
Yes, motorcycle	188 (71)	76 (29)	

Notes: * *p* value <= 0.05

Uptake of ANC visits	**Background factors between women/children with and without missing information on number of ANC visits**		***p* value χ^2**
	Frequency *(%)*		
	Without missing information on ANC	**With missing information on ANC**	
Total sample	3,419 (75)	1,137 (25)	**Total (*n*=4,556)**
Child socio-demographic characteristics			
Sex			
Male	1,726 (75)	571 (25)	0.995
Female	1,692 (75)	560 (25)	
Birth order			
1st	560 (73)	207 (27)	0.121
2nd or 3rd	1,018 (74)	367 (27)	
4th or 5th	837 (77)	255 (23)	
>=6th	716 (76)	221 (24)	
Socioeconomic level			
Level 0-2	237 (70)	100 (30)	**0.008**
Level 3	498 (72)	194 (28)	
Level 4	1,111 (76)	342 (24)	
Level 5	1,423 (77)	431 (23)	
Education (years)			
No formal education	1,683 (77)	499 (23)	**<0.001**
>=1 to 4	664 (75)	221 (25)	
>=4 to 6	554 (72)	217 (28)	
>=6	451 (70)	192 (30)	
Age (years)			
<19	4 (100)	0	0.382
>=19 to 25	353 (72)	136 (28)	
>=25 to 35	1,134 (75)	380 (25)	
>=35	1,460 (76)	465 (24)	
Ethnicity			
Fula	1,282 (77)	373 (23)	**< 0.001**
Mandinga	974 (81)	235 (19)	
Balanta	577 (66)	296 (34)	
Pepel	487 (72)	188 (28)	
Manjaco/Mancanha	26 (84)	5 (16)	
Other/Multi-ethnic	51 (60)	34 (40)	
Known history of stillbirth			
Yes	233 (74)	81 (25)	0.721
No / Primigravidae	3,180 (75)	1,054 (25)	
Household size			

< 3 children	1,781 (73)	667 (27)	**0.001**
>=3 to 6 children	1,126 (78)	315 (22)	
>= 6 children	195 (76)	62 (24)	
Village geographical characteristics			
Distance to health center			
< 2km	479 (74)	171 (27)	**0.002**
>=2 to 5km	594 (72)	228 (28)	
>=5 to 8km	763 (73)	287 (27)	
>=8km	1,537 (78)	441 (22)	

Notes: * *p* value set at <= 0.05

Approach a) All missing ANC visits replaced by less than four ANC visits

Bivariate multilevel mixed effect logistic regression for ANC coverage

(A) Health center, (B) child and maternal characteristics, and (C) village geographical

Uptake of four or more ANC visits (*n*=29 health centers)	Total (4,556 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	< 4 ANC visits 3,152 (69)	>=4 ANC visits 1,404 (31)	
Health center characteristics			
Type of Health Center			
B	439 (14)	205 (15)	1
C	2,713 (86)	1,199 (85)	0.95 (0.62, 1.44)
Emergency care (days/week)			
0	602 (19)	251 (18)	1
7	2,550 (81)	1,153 (82)	1.23 (0.75, 2.02)
Waiting time for ANC consultation (hours)			
< 2	1,318 (42)	546 (39)	1
>= 2	1,834 (58)	858 (61)	1.26 (0.93, 1.69)
ANC consultations (nº of days/week)			
5	2,892 (92)	1,326 (94)	1
7	260 (8)	78 (6)	**0.58 (0.35, 0.94)**
Reproductive Health Card cost			
No cost	2,049 (65)	853 (61)	1
Fixed cost	972 (31)	456 (32)	0.97 (0.69, 1.37)
Unfixed/unknown cost	131 (4)	95 (7)	**1.89 (1.10, 3.26)**
Quality of infrastructure			
Reasonable	928 (46)	579 (41)	1
Good	1,012 (50)	809 (58)	1.17 (0.84, 1.62)
Bad	75 (4)	16 (1)	**0.25 (0.10, 0.60)**
Evacuation vehicles and type of vehicle			
No	1,931 (61)	880 (63)	1
Yes, ambulance	1,015 (32)	466 (33)	1.14 (0.83, 1.55)
Yes, motorcycle	206 (7)	58 (4)	**0.55 (0.32, 0.96)**
Health center performs ultrasound			
Yes	469 (15)	234 (17)	1
No	2,683 (85)	1,170 (83)	0.86 (0.50, 1.48)
Lack of instruments for ANC consultation ♠			
Yes	3,0197 (98)	1,382 (98)	1
No	55 (2)	22 (2)	1.01 (0.35, 2.90)
Out-of-stock, free-of-charge ANC medicine▲			
Yes	2,559 (82)	1,201 (86)	1
No	593 (18)	203 (14)	0.78 (0.53, 1.13)
Distribution of Mosquito Net (at 1º ANC)			
Yes	2,760 (88)	1,274 (91)	1
No	392 (12)	130 (9)	0.81 (0.55, 1.19)

(A) Notes * uOR = unadjusted Odds Ratio accounted for Family group, Village and Sanitary Area with 80%CI = 80% Confidence Interval. For uOR, *p* value was set at < 0.2. ♠ Lack of instruments for ANC consultation (lack of at least one instrument): Stethoscope, Blood pressure monitor, Measure tape, HIV/malaria tests, Scale, Reproductive Health Card ▲

Out-of-stock and free-of-charge medicine (at least one group missing) :Analgesics, Antimalarials, Antiretrovirals, Anthelmintics, Antibiotics

Uptake of four or more ANC visits (*n*=29 health centers)	Total (4,556 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	< 4 ANC visits 3,152 (69)	>=4 ANC visits 1,404 (31)	
Child socio-demographic characteristics			
Sex			
Male	1,582 (50)	715 (51)	1
Female	1,564 (50)	688 (49)	0.93 (0.85, 1.02)
Birth order			
1st	500 (17)	267 (21)	1
2nd or 3rd	965 (33)	420 (33)	**0.77 (0.67,0.88)**
4th or 5th	752 (26)	340 (27)	**0.80 (0.69, .92)**
>=6th	683 (24)	254 (20)	**0.63 (0.54, 0.73)**
Maternal socioeconomic, socio-demographic and obstetric characteristics			
Socioeconomic level			
Level 0-2	259 (9)	78 (6)	1
Level 3	519 (17)	173 (13)	1.07 (0.86, 1.33)
Level 4	996 (33)	457 (34)	**1.46 (1.19, 1.79)**
Level 5	1,208 (41)	646 (48)	**1.60 (1.30, 1.97)**
Education (years)			
No formal education	1,558 (50)	624 (45)	1
>=1 to 4	601 (19)	284 (21)	**1.19 (1.05, 1.35)**
>=4 to 6	516 (17)	255 (18)	**1.31 (1.15, 1.50)**
>=6	427 (14)	216 (16)	**1.36 (1.17, 1.58)**
Age (years)			
<19	340 (11)	153 (11)	1
>=19 to 25	1,069 (34)	445 (32)	0.87 (0.74, 1.03)
>=25 to 35	1,307 (42)	618 (45)	0.96 (0.82, 1.12)
>=35	401 (13)	169 (12)	0.87 (0.72, 1.06)
Ethnicity			
Fula	1,048 (33)	607 (44)	1
Mandinga	866 (28)	343 (25)	0.88 (0.71, 1.08)
Balanta	711 (23)	161 (12)	**0.50 (0.38, 0.67)**
Pepel	427 (14)	248 (18)	1.14 (0.85, 1.53)
Manjaco/Mancanha	15 (1)	16 (1)	1.59 (0.31, 2.77)
Other/Multi-ethnic	70 (2)	18 (1)	**0.45 (0.30, 0.68)**
Known history of stillbirth			
Yes	213 (7)	101 (7)	1
No / Primigravidae	2,933 (93)	1,301 (93)	0.96 (0.80, 1.15)
Household size			
< 3 children	1,688 (59)	760 (60)	1
>=3 to 6 children	997 (35)	444 (35)	1.22 (0.99, 1.49)
>= 6 children	191 (7)	66 (5)	**1.31 (1.09, 1.57)**

(B) Notes: Missing observations: Sex (7), Birth order (21), Socioeconomic level (220), Ethnicity (26), Age (54), Education (75), Known history of stillbirth (8), Household size (4)

Uptake of four or more ANC visits (*n*=29 health centers)	Total (4,556 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	< 4 ANC visits 3,152 (69)	>=4 ANC visits 1,404 (31)	
Village geographical characteristics			
Distance to health center			
< 2km	415 (13)	235 (17)	1
>=2 to 5km	574 (18)	248 (18)	**0.62 (0.46, 0.84)**
>=5 to 8km	731 (23)	319 (23)	**0.69 (0.51, 0.93)**
>=8km	1,397 (45)	581 (42)	**0.62 (0.46, 0.82)**

(C) Notes: Missing observations: distance to health center (56)

Multivariate multilevel mixed effect logistic regression for ANC coverage

Uptake of four or more ANC visits (*n*=29 health centers)		Model I (*n*=4,556)	Model II (*n*=4,500) *	Model III (*n*=4,228) *	Model IV (*n*=4,175) *
	uOR (80%CI)		aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Sanitary Area – Level (29 clusters)					
Health center variables					
ANC consultations (nº of days/week)					
5	1		1		1
7	**0.58 (0.35, 0.94)**		0.78 (0.40, 1.52)		0.76 (0.43,1.36)
Reproductive Health Card cost					
No cost	1		1		1
Fixed cost	0.97 (0.69, 1.37)		0.79 (0.52, 1.21)		**0.73 (0.52, 1.04)**
Unfixed/ unknow cost	**1.89 (1.10, 3.26)**		1.82 (0.85, 3.88)		1.41 (0.74, 2.69)
Quality of infrastructure					
Reasonable	1		1		1
Good	1.20 (0.92, 1.57)		1.28 (0.84, 1.94)		1.20 (0.84, 1.70)
Bad	**0.25 (0.12, 0.52)**		0.19 (0.07, 0.55)		**0.26 (0.10, 0.71)**
Evacuation vehicles and type of vehicle					
No	1		1		1
Yes, ambulance	1.14 (0.83, 1.55)		0.78 (0.49, 1.24)		0.79 (0.52, 1.19)
Yes, motorcycle	**0.55 (0.32, 0.96)**		0.51 (0.23, 1.15)		0.67 (0.32, 1.42)
Village - Level (180 clusters)					
Village geographical characteristics					
Distance to health center (km)					
< 2km	1		1		1
>=2 to 5km	**0.62 (0.46, 0.84)**		0.59 (0.37, 0.94)		**0.63 (0.40, 1.00)**
>=5 to 8km	**0.69 (0.51, 0.93)**		0.64 (0.40, 1.02)		0.77 (0.47, 1.24)
>=8km	**0.62 (0.46, 0.82)**		0.54 (0.35, 0.85)		**0.59 (0.38, 0.94)**
Family group - Level (1,589 clusters)					
Child – Level					
Child socio-demographic characteristics					
Birth order					
1st	1			1	1
2nd or 3rd	**0.77 (0.67,0.88)**			0.74 (0.60, 0.90)	**0.72 (0.58, 0.88)**
4th or 5th	**0.80 (0.69, .92)**			0.63 (0.46, 0.87)	**0.63 (0.46, 0.88)**
>=6th	**0.63 (0.54, 0.73)**			0.53 (0.36, 0.78)	**0.53 (0.36, 0.79)**
Maternal socioeconomic, socio-demographic and obstetric characteristics					
Socioeconomic level					
Level 0-2	1			1	1
Level 3	1.07 (0.86, 1.33)			1.11 (0.76, 1.56)	1.10 (0.78, 1.55)
Level 4	**1.46 (1.19, 1.79)**			1.47 (1.07, 2.01)	**1.44 (1.0, 1.98)**
Level 5	**1.60 (1.30, 1.97)**			1.62 (1.18, 2.25)	**1.59 (1.15, 2.21)**

Uptake of four or more ANC visits (*n*=29 health centers) (continuation)		Model I (*n*=4,556)	Model II (*n*=4,500) *	Model III (*n*=4,228) *	Model IV (*n*=4,175) *
	uOR (80%CI)		aOR (95%CI)	aOR (95% CI)	aOR (95% CI)
Education (years)					
No formal education	1			1	1
>=1 to 4	**1.19 (1.05, 1.35)**			1.12 (0.91, 1.38)	1.14 (0.92, 1.40)
>=4 to 6	**1.31 (1.15, 1.50)**			1.24 (0.99, 1.55)	**1.25 (1.00, 1.56)**
>=6	**1.36 (1.17, 1.58)**			1.27 (0.98, 1.63)	**1.26 (0.98, 1.63)**
Ethnicity					
Fula	1			1	1
Mandinga	0.88 (0.71, 1.08)			0.90 (0.65, 1.24)	0.85 (0.61, 1.19)
Balanta	**0.50 (0.38, 0.67)**			0.52 (0.34, 0.80)	**0.55 (0.35, 0.87)**
Pepel	1.14 (0.85, 1.53)			1.19 (0.75, 1.90)	1.00 (0.61, 1.64)
Manjaco/Mancanha	1.59 (0.31, 2.77)			1.22 (0.50, 2.98)	1.21 (0.46, 2.95)
Other/Multi-ethnic	**0.45 (0.30, 0.68)**			0.41 (0.22, 0.79)	**0.39 (0.20, 0.73)**
Household size					
< 3 children	1			1	1
>=3 to 6 children	1.22 (0.99, 1.49)			1.37 (1.01, 1.86)	1.37 (1.01, 1.86)
>= 6 children	**1.31 (1.09, 1.57)**			1.19 (0.76, 1.89)	1.18 (0.74, 1.87)

Notes: * Missing observations: Distance to health center (56), Sex (7), Birth order (21), Socioeconomic level (220), Ethnicity (26), Education (75), Household size (4); uOR = unadjusted Odds Ratio; aOR = adjusted Odds Ratio; 80%CI = 80% Confidence Interval; 95%CI = 95% Confidence Interval. For uOR, *p* value was set at < 0.2, for Models II, III, and IV it was set at <=0.05

Uptake of four or more ANC visits	Model I (*n*=4,556)	Model II (*n*=4,500) *	Model III (*n*=4,228) *	Model IV (*n*=4,175) *
Measures of variation				
ICC (%) [a]	39	29	28	**25**
Sanitary Area	6	2	2	**0**
Village < Sanitary Area	13	10	9	**8**
Family group <Village<Sanitary Area	20	17	17	**16**
PCV (%) [b]	Reference	70	64	**96**
MOR[c] **(95% CI)**	2.40 (2.01, 2.79)	2.19 (1.86, 2.52)	2.20 (1.85, 2.56)	**2.11 (1.78, 2.44)**

Notes: * Missing observations: Distance to health center (56), Sex (7), Birth order (21), Socioeconomic level (220), Ethnicity (26), Education (75), Household size (4); [a] Intercorrelation cluster (ICC) [b] Proportional Change in Variance (PCV) [c] Median Odds Ratio (MOR)

Approach b) All missing ANC visits replaced by four or more ANC visits

Bivariate multilevel mixed effects logistic regression for ANC coverage

(A) Health center, (B) child and maternal characteristics, and (C) village geographical

Uptake of four or more ANC visits (*n*=29 health centers)	Total (4,556 children)		Unadjusted OR (80% CI)
	Frequency (%)		
Total sample	< 4 ANC visits 2,015 (44)	>=4 ANC visits 2,541 (56)	
Health center characteristics			
Type of Health Center			
B	264 (13)	380 (15)	1
C	1,751 (87)	2,161 (85)	0.93 (0.66, 1.31)
Emergency care (days/week)			
0	392 (19)	461 (18)	1
7	1,623 (81)	2,080 (82)	1.30 (0.87, 1.94)
Waiting time for ANC consultation (hours)			
< 2	802 (40)	1,062 (42)	1
>= 2	1,213 (60)	1,479 (58)	0.99 (0.77, 1.27)
ANC consultations (nº of days/week)			
5	1,848 (91)	2.370 (93)	1
7	117 (8)	171 (7)	0.69 (0.47, 1.03)
Reproductive Health Card cost			
No cost	1,305 (65)	1,597 (63)	1
Fixed cost	635 (32)	793 (31)	0.86 (0.65, 1.14)
Unfixed cost/unknow cost	75 (4)	151 (6)	1.51 (0.95, 2.38)
Quality of infrastructure			
Reasonable	928 (46)	1,090 (43)	1
Good	1,012 (50)	1,371 (54)	1.03 (0.80, 1.32)
Bad	75 (4)	80 (3)	0.76 (0.40, 1.41)
Evacuation vehicles and type of vehicle			
No	1,223 (61)	1,588 (63)	1
Yes, ambulance	662 (33)	819 (32)	1.05 (0.80, 1.36)
Yes, motorcycle	130 (7)	134 (5)	0.73 (0.47, 1.15)
Health center performs ultrasound			
Yes	469 (15)	234 (17)	1
No	2,683 (85)	1,170 (83)	0.86 (0.50, 1.48)
Lack of instruments for ANC consultation ♠			
Yes	1,974 (98)	2,505 (99)	1
No	41 (2)	36 (1)	0.67 (0.29, 1.58)
Out-of-stock, free-of-charge ANC medicine▲			
Yes	1,653 (82)	2,107 (83)	1
No	362 (18)	434 (17)	0.87 (0.64, 1.19)
Distribution of Mosquito Net (at 1º ANC)			
Yes	1,799 (89)	2,235 (88)	1
No	216 (11)	306 (12)	1.28 (0.93, 1.77)

(A) Notes * uOR = unadjusted Odds Ratio accounted for Family group, Village and Sanitary Area with 80%CI = 80% Confidence Interval. For uOR, *p* value was set at < 0.2♠ Lack of instruments for ANC consultation (lack of at least one instrument): Stethoscope, Blood pressure monitor, Measure tape, HIV/malaria tests, Scale, Reproductive Health Card ▲

Out-of-stock and free-of-charge medicine (at least one group missing at HC) :Analgesics, Antimalarials, Antiretrovirals, Anthelmintics, Antibiotics

Uptake of four or more ANC visits (*n*=29 health centers)	Total (4,556 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	< 4 ANC visits 2,015 (44)	>=4 ANC visits 2,541 (56)	
Child socio-demographic characteristics			
Sex			
Male	1,011 (50)	1,286 (51)	1
Female	1,004 (50	1,248 (49)	0.94 (0.86, 1.03)
Birth order			
1st	293 (16)	474 (20)	1
2nd or 3rd	598 (32)	787 (34)	**0.79 (0.69, 0.90)**
4th or 5th	497 (27)	595 (26)	**0.72 (0.63, 0.83)**
>=6th	462 (25)	475 (20)	**0.61 (0.53, 0.70)**
Maternal socioeconomic, socio-demographic and obstetric characteristics			
Socioeconomic level			
Level 0-2	159 (8)	178 (7)	1
Level 3	325 (17)	367 (15)	1.09 (0.90, 1.32)
Level 4	654 (34)	799 (33)	1.18 (0.98, 1.41)
Level 5	777 (41)	1,077 (44)	**1.36 (1.13, 1.63)**
Education (years)			
No formal education	1,059 (54)	1,123 (45)	1
>=1 to 4	380 (19)	505 (20)	**1.17 (1.04, 1.32)**
>=4 to 6	299 (15)	472 (19)	**1.37 (1.25, 1.61)**
>=6	235 (12)	408 (17)	**1.55 (1.34, 1.79)**
Age (years)			
<19	204 (10)	275 (11)	1
>=19 to 25	689 (35)	783 (33)	**0.80 (0.65, 0.99)**
>=25 to 35	842 (42)	1,045 (44)	0.85 (0.70, 1.04)
>=35	261 (13)	299 (12)	0.79 (0.62, 1.02)
Ethnicity			
Fula	675 (34)	980 (39)	1
Mandinga	631 (31)	578 (23)	0.89 (0.74, 1.08)
Balanta	415 (21)	457 (18)	**0.91 (0.72, 1.15)**
Pepel	239 (12)	436 (18)	**1.39 (1.05, 1.85)**
Manjaco/Mancanha	10 (1)	21 (1)	1.34 (0.75, 2.39)
Other/Multi-ethnic	36 (2)	52 (2)	1.09 (0.76, 1.56)
Known history of stillbirth			
Yes	132 (7)	182 (7)	1
No / Primigravidae	1,879 (93)	2,355 (93)	0.92 (0.77, 1.08)
Household size			
< 3 children	1,021 (56)	1,427 (62)	1
>=3 to 6 children	682 (37)	759 (33)	**0.78 (0.71, 0.86)**
>= 6 children	129 (7)	128 (6)	**0.70 (0.58, 0.84)**

(B) Notes: Missing observations: Sex (7), Birth order (21), Socioeconomic level (220), Ethnicity (26), Age (54), Education (75), Known history of stillbirth (8), Household size (4)

Uptake of four or more ANC visits (*n*=29 health centers)	Total (4,556 children)		Unadjusted OR (80% CI) *
	Frequency *(%)*		
Total sample	< 4 ANC visits 2,015 (44)	>=4 ANC visits 2,541 (56)	
Village geographical characteristics			
Distance to health center			
< 2km	244 (13)	406 (16)	1
>=2 to 5km	346 (17)	476 (119)	**0.70 (0.54, 0.91)**
>=5 to 8km	444 (22)	606 (24)	0.78 (0.60, 1.01)
>=8km	956 (48)	1,022 (41)	**0.59 (0.46, 0.75)**

(C) Notes: Missing observations: distance to health center (56)

Multivariate multilevel mixed effects logistic regression for ANC coverage

Uptake of four or more ANC visits (*n*=29 health centers)	uOR (80%CI)	Model I (*n*=4,556)	Model II (*n*=4,500) * aOR (95% CI)	Model III (*n*=4,181) * aOR (95% CI)	Model IV (*n*=4,129) * aOR (95% CI)
Sanitary Area – Level (29 clusters)					
Health center variables					
ANC consultations (nº of days/week)					
5	1				
7	0.69 (0.47, 1.03)				
Reproductive Health Card cost					
No cost	1				
Fixed cost	0.86 (0.65, 1.14)				
Unfixed/ unknown cost	1.51 (0.95, 2.38)				
Quality of infrastructure					
Reasonable	1				
Good	1.03 (0.80, 1.32)				
Bad	0.76 (0.40, 1.41)				
Evacuation vehicles and type of vehicle					
No	1				
Yes, ambulance	1.05 (0.80, 1.36)				
Yes, motorcycle	0.73 (0.47, 1.15)				
Village - Level (180 clusters)					
Village geographical characteristics					
Distance to health center (km)					
< 2km	1		1		1
>=2 to 5km	**0.70 (0.54, 0.91)**		0.70 (0.47, 1.04)		0.81 (0.55, 1.21)
>=5 to 8km	0.78 (0.60, 1.01)		0.78 (0.53, 1.15)		0.99 (0.65, 1.51)
>=8km	**0.59 (0.46, 0.75)**		0.59 (0.41, 0.85)		0.76 (0.51, 1.13)
Family group - Level (1,589 clusters)					
Child – Level					
Child socio-demographic characteristics					
Birth order					
1st	1			1	1
2nd or 3rd	**0.79 (0.69, 0.90)**			0.68 (0.54, 0.86)	**0.66 (0.52, 0.84)**
4th or 5th	**0.72 (0.63, 0.83)**			0.53 (0.37, 0.75)	**0.51 (0.36, 0.73)**
>=6th	**0.61 (0.53, 0.70)**			0.43 (0.29, 0.66)	**0.42 (0.28, 0.64)**
Maternal socioeconomic, socio-demographic and obstetric characteristics					
Socioeconomic level					
Level 0-2	1			1	1
Level 3	1.09 (0.90, 1.32)			1.12 (0.83, 1.52)	1.12 (0.83, 1.52)
Level 4	1.18 (0.98, 1.41)			1.17 (0.88, 1.56)	1.16 (0.88, 1.55)
Level 5	**1.36 (1.13, 1.63)**			1.35 (1.01, 1.80)	**1.35 (1.01, 1.80)**

Uptake of four or more ANC visits (*n*=29 health centers) (continuation)		Model I (*n*=4,556)	Model II (*n*=4,500) *	Model III (*n*=4,181) *	Model IV (*n*=4,129) *
	uOR (80%CI)		aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Education (years)					
No formal education	1			1	1
>=1 to 4	**1.17 (1.04, 1.32)**			1.10 (0.90, 1.34)	1.12 (0.92, 1.37)
>=4 to 6	**1.37 (1.25, 1.61)**			1.32 (1.07, 1.64)	**1.30 (1.05, 2.28)**
>=6	**1.55 (1.34, 1.79)**			1.41 (1.10, 1.79)	**1.36 (1.06, 1.73)**
Age (years)					
<19	1			1	1
>=19 to 25	**0.80 (0.65, 0.99)**			1.01 (0.77, 1.33)	1.02 (0.76, 1.35)
>=25 to 35	0.85 (0.70, 1.04)			1.61 (1.16, 2.23)	**1.64 (1.18, 2.28)**
>=35	0.79 (0.62, 1.02)			2.100 (1.39, 3.17)	**2.16 (1.43, 3.26)**
Ethnicity					
Fula	1			1	1
Mandinga	0.89 (0.74, 1.08)			0.90 (0.67, 1.21)	0.89 (0.66, 1.20)
Balanta	**0.91 (0.72, 1.15)**			0.87 (0.60, 1.26)	0.84 (0.57, 1.22)
Pepel	**1.39 (1.05, 1.85)**			1.34 (0.85, 2.10)	1.24 (0.77, 2.00)
Manjaco/Mancanha	1.34 (0.75, 2.39)			0.90 (0.36, 2.26)	0.91 (0.37, 2.27)
Other/Multi-ethnic	1.09 (0.76, 1.56)			0.92 (0.52, 1.63)	0.90 (0.51, 1.58)
Household size					
< 3 children	1			1	1
>=3 to 6 children	**0.78 (0.71, 0.86)**			0.87 (0.66, 1.56)	0.88 (0.66, 1.17)
>= 6 children	**0.70 (0.58, 0.84)**			0.75 (0.49, 1.15)	0.73 (0.48, 1.12)

Notes: * Missing observations: Distance to health center (56), Sex (7), Birth order (21), Socioeconomic level (220), Ethnicity (26), Age (54), Education (75), Household size (4); uOR = unadjusted Odds Ratio; aOR = adjusted Odds Ratio; 80%CI = 80% Confidence Interval; 95%CI = 95% Confidence Interval. For uOR, *p* value was set at < 0.2, for Models II, III, and IV it was set at <=0.05

Uptake of four or more ANC visits	Model I (*n*=4,556)	Model II (*n*=4,500) *	Model III (*n*=4,181) *	Model IV (*n*=4,129) *
Measures of variation				
ICC (%)[a]	29	29	27	**27**
Sanitary Area	4	4	3	**3**
Village < Sanitary Area	8	8	7	**7**
Family group <Village<Sanitary Area	17	17	17	**17**
PCV (%) [b]	Reference	14	29	**37**
MOR[c] (95% CI)	2.22 (1.90, 2.53)	2.17 (1.86, 2.49)	2.19 (1.86, 2.52)	**2.17 (1.84, 2.49)**

Notes: * Missing observations: Sex (7), Birth order (21), Socioeconomic level (220), Ethnicity (26), Age (54), Education (75), Household size (4); [a] Intercorrelation cluster (ICC) [b] Proportional Change in Variance (PCV) [c] Median Odds Ratio (MOR)

Supplementary information 7.

Model equations for the multivariate multilevel mixed effect logistic regression models for uptake of childhood vaccination, ANC and facility birth

Level 4: Sanitary Area [i=m members]
Level 3: Village [j =n_i members per unit i]
Level 2: Family group [k =v_{ij} members per unit j of unit i]
Level 1: Child [l =p_{ijk} members per unit k of unit j of unit i]

1. **<u>Vaccination coverage</u>**

a) Model I- intercept only, no independent variables

$$logit \Pr(Fully\ vaccinated_{ijkl} = yes) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$

b) Model II- with selected health center characteristics

$$logit \Pr(Fully\ vaccinated_{ijk} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk} + \beta_1 \text{ Type of healthcenter}_i + \beta_2 \text{Quality of infrastructure}_i$$

c) Model III- with selected child and maternal characteristics

$$logit \Pr(Fully\ vaccinated_{ijkl} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk} + \beta_3 \text{ Maternal age}_{ijkl} + \beta_4 \text{Household size}_{ijkl}$$

d) Model IV- with selected child and maternal and health center characteristics

$$logit \Pr(Fully\ vaccinated_{ijkl} = yes) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk} + \beta_1 \text{ Type of healthcenter}_i + \beta_2 \text{Quality of infrastructure}_i + \beta_3 \text{ Maternal age}_{ijkl} + \beta_4 \text{Household size}_{ijkl}$$

2. **Antenatal Care coverage**

a) Model I- intercept only, no independent variables

$$logit \Pr(Four\ or\ more\ ANC_{ijkl} = yes) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$

b) Model II- with selected health center and village geographical characteristics

$$logit \Pr(Four\ or\ more\ ANC_{ijk} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$
$$+\beta_1 \text{Reproductive health card cost}_i$$
$$+\beta_2 \text{Quality of infrastructure}_i + \beta_3 \text{Evacuation vehicles}_i +$$
$$\beta_4 \text{Number of} \frac{\text{days}}{\text{week}} \text{of ANC consulation}_i + \beta_5 \text{Distance to health center}_{ij}$$

c) Model III- with selected child and maternal characteristics

$$logit \Pr(Four\ or\ more\ ANC_{ijkl} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$
$$+\beta_6 \text{Birth order}_{ijkl} + \beta_7 \text{Socioeconomic index}_{ijkl} + +\beta_8 \text{Ethnicity}_{ijkl} + \beta_9 \text{Age}_{ijkl}$$
$$+ \beta_{10} \text{Education}_{ijkl} + +\beta_{11} \text{Household size}_{ijkl}$$

d) Model IV- with selected child and maternal, and health center and village geographical characteristics

$$logit \Pr(Four\ or\ more\ ANC_{ijk} = yes|selected\ variables)$$
$$= \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$
$$+\beta_1 \text{Reproductive health card cost}_i$$
$$+\beta_2 \text{Quality of infrastructure}_i + \beta_3 \text{Evacuation vehicles}_i +$$
$$\beta_4 \text{Number of} \frac{\text{days}}{\text{week}} \text{of ANC consulation}_i + \beta_5 \text{Distance to health center}_{ij} + \beta_6 \text{Birth order}_{ijkl} +$$
$$\beta_7 \text{Socioeconomic index}_{ijkl} + +\beta_8 \text{Ethnicity}_{ijkl} + \beta_9 \text{Age}_{ijkl} + \beta_{10} \text{Education}_{ijkl} +$$
$$+\beta_{11} \text{Household size}_{ijkl}$$

3. Facility birth coverage

a) Model I- intercept only, no independent variables

$$logit \Pr(Facility\ birth_{ijkl} = yes) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$

b) Model II- with selected health center and village geographical characteristics

$$logit \Pr(Facility\ birth_{ijkl} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk} +$$
$$\beta_1 \text{Quality of infrastucture}_i + \beta_2 \text{Pre or post partum room exlusive for women}_i + \beta_3 \text{Evacuation vehicles}_i +$$
$$\beta_4 \text{Distance to health center}_{ij}$$

c) Model III- with selected child and maternal characteristics

$$logit \Pr(Facility\ birth_{ijkl} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk}$$
$$+\beta_5 \text{Season of the year}_{ijkl} + \beta_6 \text{Birth order}_{ijkl} + \beta_7 \text{Socioeconomic index}_{ijkl} + \beta_8 \text{Ethnicity}_{ijkl}$$
$$+ \beta_9 \text{Age}_{ijkl} + +\beta_{10} \text{Education}_{ijkl}$$
$$+ \beta_{11} \text{Mother attended at least one ANC}_{ijkl}$$
$$+ \beta_{12} \text{Known history of facility birth}_{ijkl} + \beta_{13} \text{Household size}_{ijkl}$$

d) Model IV- with selected child and maternal, and health center and village geographical characteristics

$$logit \Pr(Facility\ birth_{ijkl} = yes|selected\ variables) = \beta_0 + \beta_{0i} + \beta_{0ij} + \beta_{0ijk} +$$
$$\beta_1 \text{Quality of infrastucture}_i + \beta_2 \text{Pre or post partum room exlusive for women}_i + \beta_3 \text{Evacuation vehicles}_i$$
$$+ \beta_4 \text{Distance to health center}_{ij} + \beta_5 \text{Season of the year}_{ijkl} + \beta_6 \text{Birth order}_{ijkl} +$$
$$\beta_7 \text{Socioeconomic index}_{ijkl} + \beta_8 \text{Ethnicity}_{ijkl} + \beta_9 \text{Age}_{ijkl} + +\beta_{10} \text{Education}_{ijkl} +$$
$$\beta_{11} \text{Mother attended at least one ANC}_{ijkl} + \beta_{12} \text{Known history of facility birth}_{ijkl} +$$
$$\beta_{13} \text{Household size}_{ijkl}$$