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Regional, subregional and country-level full vaccination coverage in children aged 12–23 months for 34 countries in sub-Saharan Africa: a global analysis using Demographic and Health Survey data

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ABSTRACT

Objective This study estimated the proportion of children aged 12–23 months who were fully vaccinated in sub-Saharan Africa (SSA), explored geographical disparities across subregions and countries, and identified country-level factors associated with full vaccination (FV).

Design Cross-sectional study.

Setting SSA.

Participants Children aged 12–23 months.

Primary outcome FV.

Methods Data for this study were extracted from the most recent Demographic and Health Survey (DHS) conducted in 34 SSA countries between 2012 and 2023. The study included a total weighted sample of 69 218 children. Univariate analyses were performed to describe the socio-demographic profile of the participants and estimate the proportion of FV and the proportion for each of the eight vaccines (BCG, DTP1, DTP2, DPT3, Polio1, Polio2, Polio3, Measles1) at regional level. Bivariate and spatial analyses were produced to examine existing disparities at regional, subregional and countries' income levels. A multivariate logistic regression analysis was fitted for identifying country-level factors associated with FV.

Results 54.1% (95% CI 53.7% to 54.5%) children aged 12–23 months in SSA were fully vaccinated. In addition, substantial inequalities emerged in FV coverage across countries ranging from 23.9% in Guinea to a high of 95.5% in Rwanda. The same pattern was observed for the eight vaccines. Findings also showed that children of birth order 3 and above, who were delivered at home, had received less than four antenatal visits, from poor households and households with more than 5 members, whose mothers were under 25, had primary education level and below, and had no income-generating activities were less likely to be fully vaccinated.

Conclusion To achieve WHO's global vaccination coverage target of 90% by 2030 in SSA, vaccination programmes must take account of regional, subregional and national inequities. Our findings also underline the need for interventions tailored to each SSA country's socio-cultural context.

Ethical consideration Ethical approval was not required as this is a secondary analysis of publicly available data.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prior studies that addressed childhood vaccination in sub-Saharan Africa (SSA) focused on a single country or a group of countries in the region.
⇒ Bacillus Calmette–Guérin (BCG) was the most widely administered vaccine in SSA.

WHAT THIS STUDY ADDS

⇒ To our knowledge, this study presents comparable national estimates on full vaccination among children 12–23 months in 34 SSA countries that have conducted recent Demographic and Health Surveys (some during COVID-19).
⇒ Within the context of generally low full vaccination coverage, there were marked inequities across SSA countries and subregions, with the lowest full vaccination coverage in Central Africa and West Africa, and the highest in Southern Africa.
⇒ The countries with the best coverage in SSA were generally small. By contrast, many large countries had low coverage.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Multifaceted efforts must be expedited to quickly scale up coverage with all vaccines across SSA, especially in West and Central African countries.
⇒ 'The Big Catch-up' initiative of GAVI must be promptly customised and adopted by each SSA country to adequately address the access and utilisation barriers to vaccination uptake.

INTRODUCTION

Vaccination has been pivotal in reducing vaccine-preventable diseases (VPDs) and decreasing childhood mortality and morbidity in low-income and middle-income countries, particularly those in sub-Saharan Africa (SSA). Over the past five decades, remarkable improvements have been made in immunisation programmes. In the early 1970s, WHO established the Expanded Programme on Immunization (EPI) with the goal of immunising every child against six VPDs (ie, diphtheria, pertussis, tetanus (DPT), poliomyelitis, measles and tuberculosis) by 1990.[1] The implementation of the EPI as well as subsequent global goals, such as those outlined in the Sustainable Development Goals (SDGs) Target 3.b, the Global Vaccine Action Plan[2] and the Regional Strategic Plan for Immunization in Africa,[3] have been a global success, with vaccination averting 154 million deaths, including 146 million among children younger than 5 years.[4] However, despite the significant progress and efforts to increase immunisation coverage, SSA continues to face challenges in achieving high coverage as recommended by WHO for children aged 12–23 months, with disparities in full vaccination (FV) rates observed across countries and subregions.[5] Consequently, many children in the region remain undervaccinated, contributing to persistent outbreaks of diseases that are otherwise preventable.[5 6]

To address these challenges, governments, non-governmental organisations (NGOs) and international agencies have been implementing various strategies aimed to close the gaps in immunisation and ensure that children receive critical vaccines on time, protecting them from preventable diseases. For instance, several governments in SSA such as Rwanda,[7] Kenya[8] and Ghana[9] have introduced routine immunisation schedules, integrated childhood vaccines into primary healthcare systems and used outreach strategies to reach hard-to-access communities, such as mobile vaccination units and community health worker programmes.[10] NGOs like Médecins Sans Frontières and Save the Children have played a crucial role in enhancing vaccine delivery through targeted immunisation campaigns, strengthening supply chains and training caregivers about the importance of timely vaccination.[11] Multilateral agencies such as GAVI, the Vaccine Alliance and WHO have driven global initiatives, including the Immunization Agenda 2030, which focuses on increasing access to vaccines for children in low-income and conflict-affected regions.[12] Additionally, partnerships between the public and private sectors have helped reduce vaccine costs and improve the availability of vaccines. Strategies like door-to-door vaccination drives, the use of digital health platforms for tracking immunisation records and the deployment of vaccine refrigerators in remote areas have also proven successful in increasing coverage among this vulnerable age group.[13] These efforts collectively strive to eliminate immunisation gaps and guarantee that children receive essential vaccines promptly, safeguarding them from preventable illnesses.

Due to incompleteness and paucity of administrative data in most SSA countries, in recent years, the Demographic and Health Surveys (DHS) have emerged as a critical source of data in tracking vaccination coverage across countries. The DHS provides standardised, nationally representative data, enabling detailed analyses of vaccination trends and their correlates at the subregional and country levels. However, multicountry analyses systematically comparing vaccine coverage across several SSA regions and within countries are relatively scarce. Such comparative studies are essential for identifying both common and unique factors influencing vaccine uptake across different contexts, as well as for highlighting subregions that require targeted interventions.[14] While previous studies have focused on individual countries or small subregions within SSA, a broader, multicountry analysis is necessary to capture the diverse trends in vaccination coverage across the subcontinent. Such analyses are critical for identifying common challenges and successes that can be addressed through regional or global health initiatives. In this regard, this study aims to document FV among children aged 12–23 months in SSA. The research will explore the disparities in FV coverage and identify the key factors related to undervaccination by conducting a subregional and country-level analysis. Moreover, this study contributes to global health efforts, particularly within the context of the SDGs, which emphasise the importance of universal health coverage and reducing child mortality.[15]

METHODS

Data source

Data for this study were extracted from the most recent DHS conducted in 34 SSA countries between 2012 and 2023. These countries were grouped into four WHO regions.[16] When a country has carried out two surveys during the 2012–2023 period, data from the most recent survey have been incorporated (table 1).

DHS is a comparable nationally representative survey undertaken regularly in over 90 countries, enhancing a global understanding of developing country health and demographic trends. Further, the DHS data were divided into several modules, including Household (HR), Women (IR), Men (MR), Children (KR), Births (BR) and Couples (CR). The birth recode file contains information relating to the survival status of all children born in 5 years prior to the survey, vaccination status, as well as the socio-economic and cultural characteristics of their mothers.

Population study and management of missing observations

For this study, child data sets from 34 SSA countries were pooled. All observations that contained such missing information were excluded. Ultimately, our analysis

Table 1 Selected countries by survey year and WHO regions

Central	Eastern	Southern	Western
Angola (2016)	Burundi (2017)	Lesotho (2014)	Benin (2018)
Cameroon (2018)	Comoros (2012)	Namibia (2013)	Burkina Faso (2021)
Chad (2015)	Ethiopia (2019)	South Africa (2016)	Côte d'Ivoire (2021)
Congo DR (2014)	Kenya (2022)	Zambia (2018)	Gambia (2020)
Gabon (2021)	Madagascar (2021)	Zimbabwe (2015)	Ghana (2022)
	Malawi (2016)		Guinea (2018)
	Mozambique (2023)		Liberia (2020)
	Rwanda (2020)		Mali (2018)
	Tanzania (2022)		Mauritania (2021)
	Uganda (2016)		Niger (2012)
			Nigeria (2018)
			Senegal (2023)
			Sierra Leone
			Togo (2014)

encompassed a weighted sample of 69 218 children aged 12–23 months (see online supplemental figure 1).

Variable selection and measurement

Outcome variable

The outcome variable was the vaccination status of children, coded as dummy responses, with 1 for 'fully vaccinated' and 0 for 'not fully vaccinated'. A child who received all the eight recommended vaccines (one dose of BCG, three doses of DTP, three doses of polio and one dose of measles) is considered fully vaccinated. The survey enumerators acquired the vaccination status of children from documented vaccine records or through the maternal verbal report in instances where vaccination cards were unavailable.

Independent variables

These include socio-demographic, community, household, maternal and children characteristics, such as subregions ("Central Africa", "Eastern Africa", "Southern Africa", "Western Africa"), place of residence ("urban", "rural"), household size ("less than 4", "4–5", "more than 5"), community medial level ("high", "low"), wealth index ("poorest", "poorer", "middle", "richer", "richest"), type of facility ("health facility", "home/others"), mother's age ("less than 25", "25–34", "35–44", "45 and above"), mother's education level ("primary and below", "secondary", "higher"), mother's occupation ("yes", "no"), marital status ("never in union", "in union", "divorced/separated/widowed"), sex of child ("male", "female"), birth order ("1", "2", "≥3") and number of antenatal visits ("less than 4", "4–8", "9 and above"). All the explanatory variables were derived from a comprehensive literature review[17–22] as well as their availability in the child data sets.

Statistical analysis

Our analysis was conducted in different steps. First, univariate descriptive statistics were used to provide an overview of the study population and estimate the proportion of FV and the coverage for each of the eight vaccines at global level. Second, bivariate and spatial analyses were produced to observe vaccination coverage (FV and for each of the eight vaccines) at the national, regional and subregional levels. We also used the World Bank Income Classification to categorise all studied countries by income level. A logistic regression was estimated to identify country-level significant factors associated with FV in SSA. Results were reported as adjusted ORs (aORs) with their 95% CIs. The criterion for statistical significance was established as $p<0.05$. The variance inflation factor was applied to assess multicollinearity. Throughout the analytical process, data were weighted to ensure the representativeness of the DHS sample and carried out in R 4.4.1 and STATA 18.0 (StataCorp). We followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

Patient and public involvement

No patient is involved.

RESULTS

Socio-demographic profile of study population

Online supplemental table 1 depicts the socio-demographic characteristics of the study population. Nearly 40.0% of the children were from Western Africa, 31.4% from Eastern Africa, 17.5% from Central Africa and 7.8% from Southern Africa. Slightly more than half (50.8%) of the children were male, and 66.3% lived in rural areas. Around a third had mothers with no income-generating activities, 44.0% were in the poorest/poorer

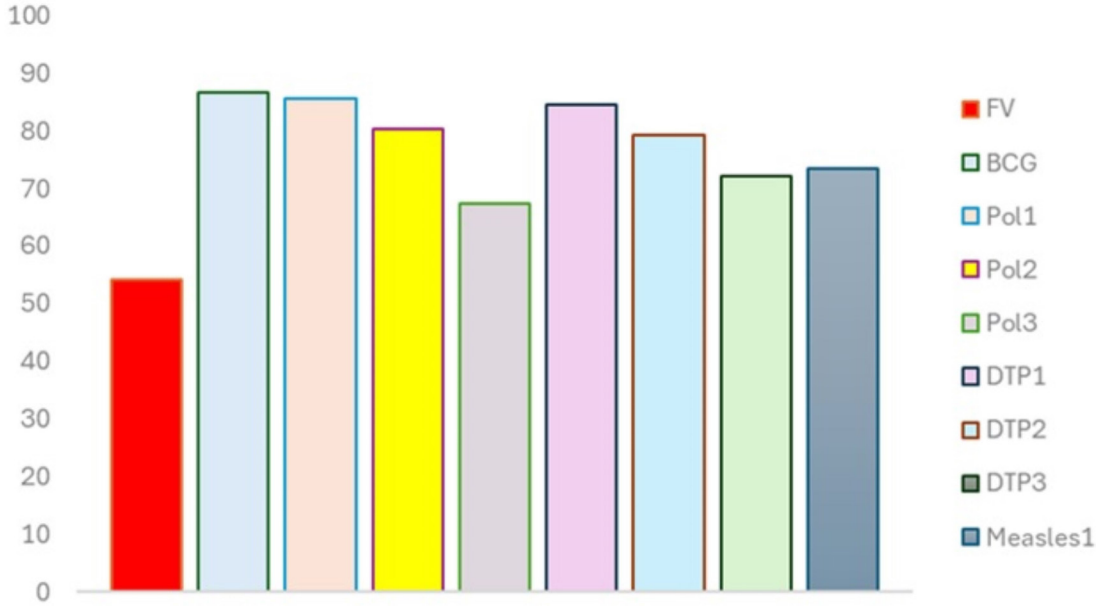

Figure 1 Immunization coverage for eight vaccines and complete vaccination status in SSA. BCG, Bacillus Calmette-Guérin vaccine; DTP, Diphtheria-tetanus-pertussis vaccine; FV, full vaccination; Pol, Polio vaccine.

wealth index quintiles, 56.1% came from households with more than five members and 60.4% were from communities with low media exposure. Most children (75.7%) were delivered at public/private health facility, and 22.8% were their mother's first child. A third were to mothers under 25, over two-thirds (68.0%) had mothers with a primary or no formal education and 86.1% had their mothers in union. For 51.6% of them, their mothers had received 4–8 antenatal visits during pregnancy.

Immunisation coverage of eight vaccines and FV

Figure 1 presents the immunisation coverage for eight vaccines and complete vaccination status in SSA. Overall, 54.1% (95% CI 53.7% to 54.5%) of children were fully vaccinated in SSA. Coverage was higher for BCG (86.6%; 95% CI 86.3% to 86.9%) and Polio1 (85.6%; 95% CI 85.3% to 85.9%), while it was lower for Polio3 (67.5%; 95% CI 67.2% to 67.8%) and DTP3 (72.2%; 95% CI 71.9% to 72.5%). Additionally, more than 80.0% of children in SSA had received BCG, Polio1, Polio2 and DTP1.

Disparities in complete vaccination coverage among nations within SSA

Figure 2 includes information on disparities in complete vaccination coverage among nations within SSA. While the proportion of fully vaccinated children is relatively low in SSA, it masks significant disparities between countries in this region. The proportion of FV coverage ranged from 23.^{9}% to 95.^{5}% in SSA. Countries such as Guinea (23.9%; 95% CI 19.3% to 28.5%), Chad (26.0%; 95% CI 22.8% to 29.1%), Angola (30.6%; 95% CI 27.4% to 33.8%), Nigeria (31.2%; 95% CI 29.1% to 33.3%), Côte d'Ivoire (35.7%; 95% CI 32.0% to 39.4%), Mauritania (37.9%; 95% CI 34.6% to 41.3%) and Mozambique (37.9%; 95% CI 34.2% to 41.5%) had the lowest proportions of fully vaccinated children, while in Gambia, Burundi and Rwanda the proportion was over 80.0%. Globally, only Rwanda reached 90.0% or higher average coverage across all eight vaccines.

There was also an effect of country size. The countries with the best coverage were generally small. By contrast, many large countries had low coverage.

Disparities in vaccine type among countries in SSA

Figure 3 shows the vaccination coverage by country and each type of vaccine. BCG vaccine is one of the most widely used vaccines in SSA. 12 countries (Burkina Faso, Burundi, Gambia, Ghana, Kenya, Lesotho, Malawi, Uganda, Rwanda, Sierra Leone, Togo and Zambia) reached 95.0% or higher coverage. By contrast, six countries (Angola, Guinea, Madagascar, Nigeria, Chad and Ethiopia) had below 80.0% coverage. Chad was the only country with BCG coverage below 60.0%. For Polio1, seven countries (Burundi, Gambia, Ghana, Kenya, Malawi, Rwanda and Zambia) had at least 95.0% coverage, and three countries (Angola, Guinea and Nigeria) recorded coverage below 75.0%. For Polio2, 2 countries (Burundi and Rwanda) were at least 95.0% coverage, and 10 (Angola, Côte d'Ivoire, Gabon, Guinea, Madagascar, Mali, Mozambique, Nigeria, Chad and Ethiopia) had recorded coverage below 75.0%. For Polio3, only Rwanda had reached coverage of over 95.0%. Further, Burundi and Gambia recorded coverage levels ranging from 91.0% to 93.0%, and Angola, Guinea, Mauritania and Nigeria had coverages below 50.0%.

For DTP1, eight countries (Burundi, Gambia, Ghana, Kenya, Lesotho, Malawi, Rwanda and Zambia) had at least 95.0% coverage, whereas only three countries (Guinea, Nigeria and Chad) had coverages below 65.0%. Five countries (Burundi, Gambia, Malawi, Rwanda and Zambia) exceed 95.0% coverage for DTP2. On the other

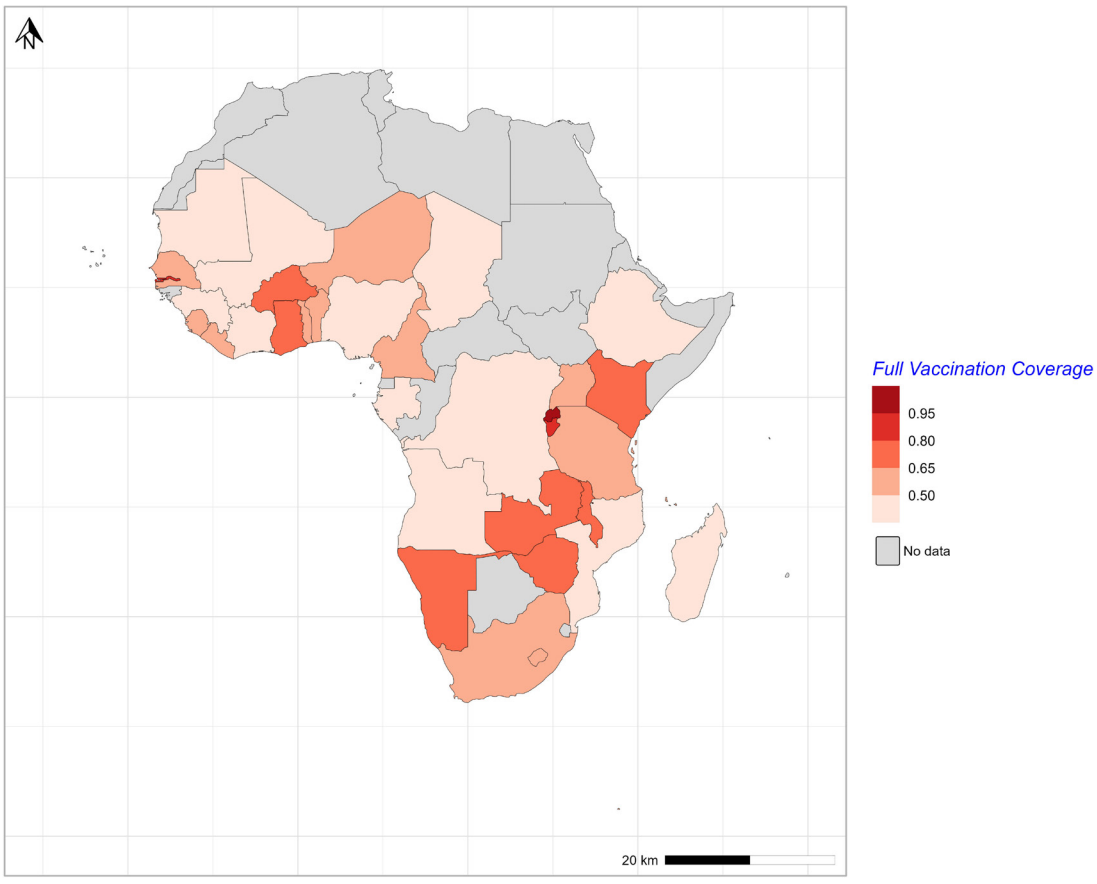

Figure 2 Full vaccination coverage or proportion of fully vaccinated children (ie, proportion of children aged 12–23 months who have received all eight vaccines) by country. Note: Countries highlighted in grey are those for which data is either unavailable or outdated.

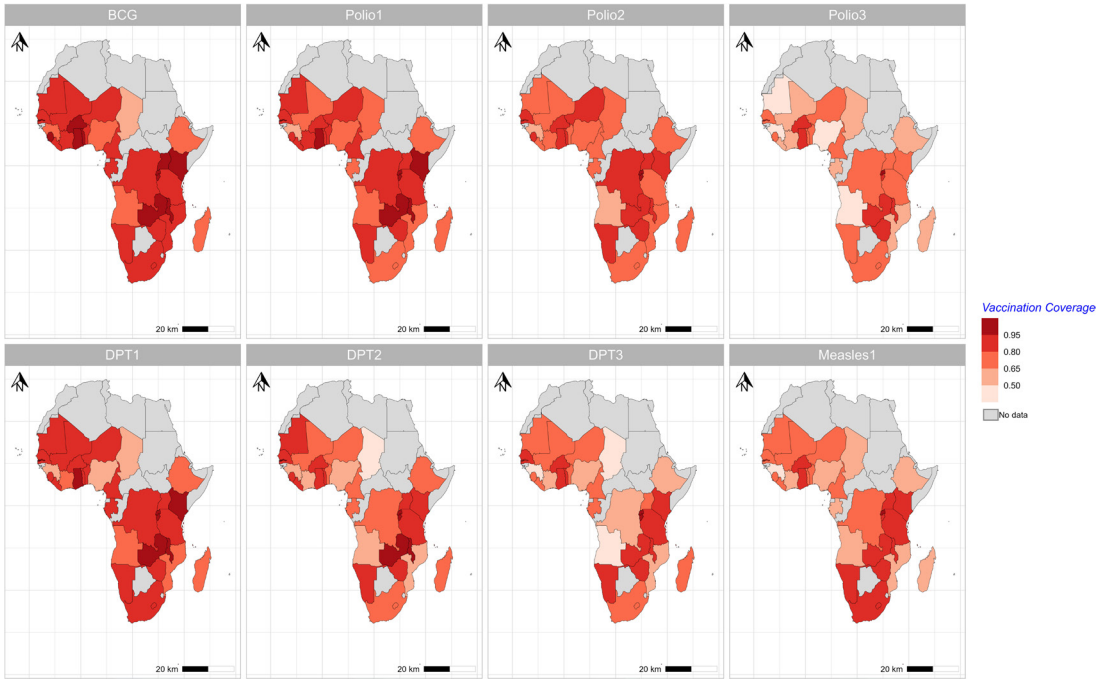

Figure 3 Vaccination coverage by country and by each type of vaccine. Note: Countries highlighted in grey are those for which data is either unavailable or outdated. BCG, Bacillus Calmette-Guérin vaccine; DTP, Diphtheria-tetanus-pertussis vaccine.

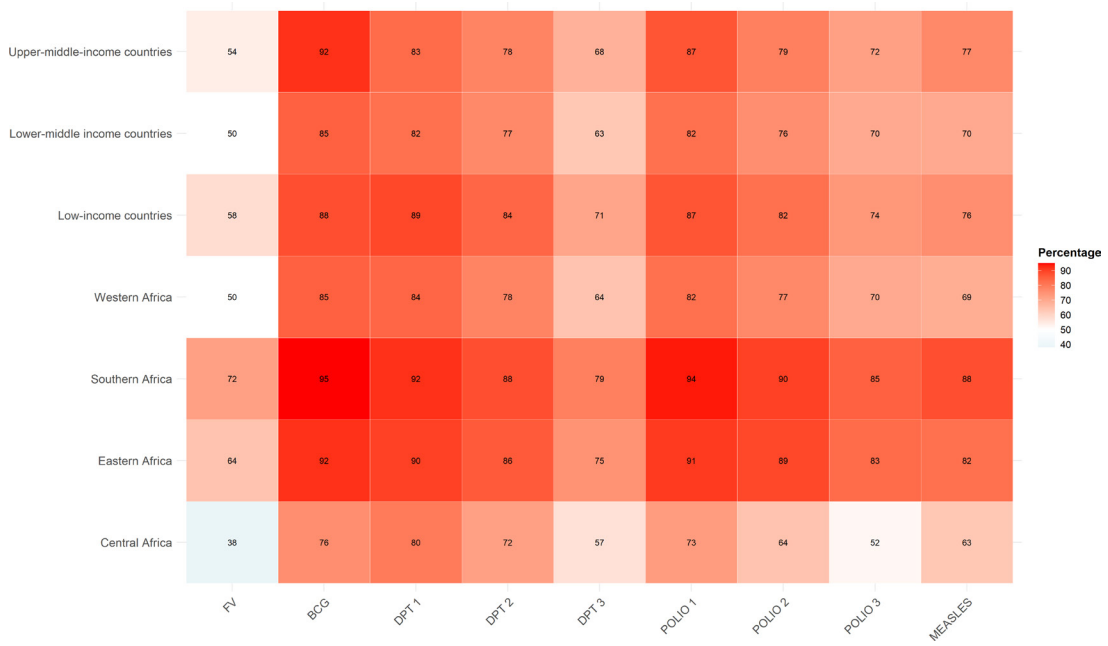

Figure 4 Vaccination coverage by WHO African regions and different income groups for each type of vaccine. BCG, Bacillus Calmette-Guérin vaccine; DTP, Diphtheria-tetanus-pertussis vaccine; FV, Full Vaccination.

hand, Nigeria (57.8%; 95% CI 56.1% to 59.4%), Angola (51.5%; 95% CI 48.8% to 54.2%) and Chad (48.6%; 95% CI 46.0% to 51.2%) also had the lowest DTP2 coverage rates. Regarding DTP3, Burundi and Rwanda were the only countries with coverage rates of over 95.0%. Moreover, Angola, Guinea and Chad had coverages below 50.0%. Finally, concerning Measles1, only Rwanda had reached coverage of over 95.0%. DTP3 vaccination coverage in countries like Angola, Guinea, Nigeria and Ethiopia was below 60.0%. Many countries in SSA (n=14) had DTP3 vaccination coverage levels of between 60.0% and 75.0%.

Vaccination coverage by WHO regions and different income groups

Figure 4 presents variations in FV across different regions of SSA. Among the four WHO regions, the Central Africa region (which includes countries such as Angola and Chad) had the lowest coverage (38.2%; 95% CI 36.7% to 39.6%), while the Southern Africa region had the highest (71.5%; 95% CI 70.1% to 72.9%). The same findings emerged across all the eight vaccines.

Also, there were important disparities in childhood vaccination coverage by countries' income levels. Lower-middle-income countries had lower childhood vaccination coverage than upper-middle-income and low-income countries. For instance, coverage rates for FV were 50.1% (95% CI 49.3% to 50.9%), 54.4% (95% CI 51.9% to 56.8%) and 58.0% (95% CI 57.3% to 58.6%), respectively.

Vaccination coverage by selected socio-demographic characteristics of children

Online supplemental table 2 provides information on FV coverage by selected socio-demographic factors of children. There was no significant difference between the proportion of fully vaccinated males (54.2%) and females (54.1%) in SSA. The proportion of FV was 55.8% in urban areas, while it was 53.3% in rural areas. We also found that FV was much higher among children from households with less than four members (57.1%) than those from households with more than five members (52.9%). Further, the proportion of fully vaccinated children was 52.0% for mothers under 25, 55.3% for those aged 25–34, 55.8% for those aged 35–44 and 45.8% for those aged 45 and above. Similarly, FV was most common among children whose mothers had a higher education level (69.8%), and least common among those whose mothers had primary education and below (50.1%). FV was almost similar in children whose mothers had an income-generating activity and in those whose mothers had no income-generating activities (54.8% and 52.8%, respectively). Moreover, FV was most common in children from the wealthiest households (63.4%), from communities with high media exposure (62.1%), whose mothers had never been married (57.3%) and whose mothers had received 4–8 antenatal visits during pregnancy (60.8%). Turning to birth order, the proportion of FV was much higher among first-born children (58.2%) and those delivered in health facilities (61.2%).

The proportion of different types of vaccine by selected socio-demographic variables is presented in online supplemental table 3. Trends are like those seen above. Vaccination coverage (for each of the eight vaccines) was higher in Southern Africa, urban areas, communities with high media level, households with less than four members, richest households, first-born children, children delivered in health facilities, children whose mothers had never been married, had received 4–8

antenatal visits during pregnancy and aged 25–24 and 35–44.

Factors associated with childhood FV in SSA

Online supplemental figure 2 displays results from the final model. Children from Southern Africa (aOR=2.20; 95% CI 2.05 to 2.35) and Eastern Africa (aOR=1.72; 95% CI 1.65 to 1.79) were more likely to be fully vaccinated compared with those from Western Africa. Conversely, the odds of FV among children from Central Africa (aOR=0.66; 95% CI 0.63 to 0.69) decreased by 34% compared with their counterparts from Western Africa. Children from households with less than four members (aOR=0.91; 95% CI 0.86 to 0.97) and households with 4–5 members (aOR=0.94; 95% CI 0.91 to 0.98) were found to have a lower probability of FV. Children from rural areas were 1.3 times more likely to receive the eight vaccines (aOR=1.31; 95% CI 1.26 to 1.37) than those from urban areas. Children from the richest (aOR=1.52; 95% CI 1.42 to 1.62), richer (aOR=1.33; 95% CI 1.26 to 1.41), middle (aOR=1.25; 95% CI 1.19 to 1.32) and poorer (aOR=1.13; 95% CI 1.07 to 1.18) households had greater odds of FV compared with those from the poorest households. Likewise, the odds of FV among children delivered in health facilities were 2.5 times higher (aOR=2.49; 95% CI 2.39 to 2.59) than that of children who were delivered at home. Children whose mothers were aged 25–34 (aOR=1.25; 95% CI 1.19 to 1.31) and 35–44 (aOR=1.38; 95% CI 1.30 to 1.47) were found to have greater odds of FV compared with those aged less than 25. Furthermore, children whose mothers had secondary (aOR=1.26; 95% CI 1.21 to 1.32) and higher education level (aOR=1.46; 95% CI 1.33 to 1.60) were more likely to be completely vaccinated compared with those whose mothers had primary level and below. The likelihood of FV was significantly higher among children whose mothers had an income-generating activity (aOR=1.12; 95% CI 1.08 to 1.16) than those whose mothers had no income-generating activities. In addition, the results revealed that children whose mothers had been never married (aOR=1.14; 95% CI 1.04 to 1.25) and in union (aOR=1.29; 95% CI 1.20 to 1.38) were more likely to be fully vaccinated compared with those whose mothers were divorced/separated/widowed. Children of the first (aOR=1.22; 95% CI 1.15 to 1.29) and second (aOR=1.10; 95% CI 1.04 to 1.15) birth order were at least 1.1 times more likely to be fully vaccinated than children of birth order 3 and above. Finally, children whose mothers had received 4–8 (aOR=1.46; 95% CI 1.41 to 1.51) and 9 and above (aOR=1.15; 95% CI 1.09 to 1.22) antenatal visits during pregnancy were more likely to be completely immunised with the eight vaccines than children whose mothers received less than four antenatal visits.

DISCUSSION

This study aimed to document FV coverage in SSA, a region where under 5 mortality rates remain persistently high. Specifically, this study evaluated the proportion of children aged 12–23 months who were fully vaccinated, explored geographical disparities across subregions and countries, and identified factors associated with FV coverage in SSA.

Summary of results

Globally, 54.1% (95% CI 53.7% to 54.5%) children aged 12–23 months were fully vaccinated in SSA. BCG was the most widely administered vaccine (86.6%; 95% CI 86.3% to 86.9%), while Polio3 (67.5%; 95% CI 67.2% to 67.8%) and DPT3 (72.2%; 95% CI 71.9% to 72.5%) were the least administered. Further, dropout rates between DPT1-DPT3 and Polio1-Polio3 were high (21.1% and 14.5%, respectively) (see online supplemental tables 4 and 5). The results also revealed that Southern Africa had higher child vaccination coverages, whereas Central and Western Africa had lower rates. Similarly, substantial inequalities emerged in FV coverage across countries ranging from 23.9% (95% CI 19.3% to 28.5%) in Guinea to a high of 95.5% (95% CI 94.4% to 96.5%) in Rwanda. The same pattern was observed for the eight vaccines. In addition, we found that low FV coverage in SSA was significantly associated with geographical and socio-economic factors.

FV coverage in SSA is far from the 90% target by 2030

FV coverage in SSA was far from the 90% target set by WHO for 2030. Conflicting public health priorities, political instabilities, suboptimal community engagement, inefficient and ineffective health systems, insufficient financial resources, as well as social vulnerabilities may substantially account for this low vaccination coverage.[16 23] Societal, cultural and religious pressures also contribute to the low vaccination coverage level across the region.[24]

BCG is the most prevalent vaccine and DPT3/Polio3 the least prevalent in SSA

Findings showed that BCG was the most widely used of all eight vaccines in SSA. The only vaccine against tuberculosis, BCG is administered immediately after childbirth as a single dose.[25] In 45 out of 48 countries in SSA, BCG is scheduled at birth.[26] Moreover, our data indicated that over three-quarters of children aged 12–23 months in SSA were delivered in health facilities. This may explain the relatively high coverage rate of BCG in some subregions. Although the BCG vaccine is provided free of charge in SSA, parents must pay for vaccination cards and syringes in some countries, which are obstacles to early BCG vaccination and attaining the 90% target.[27]

Conversely, DPT3 and Polio3 were the least frequent, partly due to the repeated visits required for these vaccines.[28] The DPT1 and Polio1 coverages in SSA were high (≥ 80%), an indicator of good access to vaccination-related services.[29] On the other hand, the rates of Polio1-to-Polio3 and DPT1-to-DPT3 dropout were higher than the WHO 10% threshold,[30] clearly indicating a region-wide problem with the utilisation of vaccination services.[29]

The same conclusion may apply to the polio vaccine. Inadequate health service monitoring, low access to sufficient health information, distance and/or travel time to reach healthcare centres (issues in rural/remote areas), coupled with economic vulnerabilities, are likely reasons for high vaccination dropouts in SSA.[31 32]

Western and Central Africa: the most vulnerable subregions in terms of FV coverage

Another important finding was that Western and Central Africa were the most vulnerable subregions regarding FV coverage. Factors contributing to these figures are multifaceted. First, of the 19 Central and Western African WHO countries considered in our study, 10 are consistently ranked among the 20 countries with the lowest Human Development Index in the world.[33] Besides, the majority of countries in these subregions (14/19) allocate less than 5% of their Gross Domestic Product to healthcare expenditure,[34] reflecting a low priority given to the health sector, which may explain partly the lower immunisation system performance.[23 35] Second, Western and Central African WHO regions have been heavily affected by repeated armed conflicts over the past two decades,[35 36] which have disrupted immunisation services and affected FV coverage.[37] During these conflicts, children in these regions also face multiple deprivations related to drinking water, quality food and access to other health services.[38 39] Third, the 2014–2016 Ebola outbreaks played an essential role in their very low childhood vaccination coverage. Almost half of our study's Western and Central African WHO region countries had carried out their last DHS during or just after the Ebola outbreaks. During this period, there was a deprioritisation of routine healthcare, including vaccination services, in favour of the treatment of patients with Ebola and disease prevention.[40] Childhood vaccination services were even suspended in some districts/areas affected due to the reallocation of health workers to Ebola prevention activities.[40] Moreover, families were very reluctant to vaccinate their children against preventable diseases in health centres out of fear of contracting the virus,[41] creating another public health crisis.

Extreme disparities in FV coverage across countries in SSA

There were important inequities across the countries in FV coverage. The highest proportions of children fully vaccinated were in Rwanda and Burundi. In Rwanda, this observation may be partially due to its strong leadership, the implementation of robust decentralised childhood immunisation programmes and community involvement,[42] whereas Burundi receives ongoing funding from external organisations such as the GAVI Alliance and the Measles and Rubella Initiative.[43] By contrast, Angola, the Democratic Republic of Congo, Nigeria, Ethiopia and Guinea were among the countries with the lowest FV coverage. These countries have high fertility rates and large populations of children under the age of 2 years. This demographic situation puts pressure on their health systems and may contribute to a large number of undervaccinated children.[42 44] Healthcare system weaknesses caused by underfunding of vaccination programmes and constant political instability in some countries in SSA are also very likely contributors to low vaccination coverage.[29] There was also a negative correlation between vaccination coverage and the size of countries. Globally, countries with high vaccination coverage were among the smallest in geographical size, while those with low coverage were primarily among the largest countries. This is an important issue that has been largely overlooked in the extant literature on childhood vaccination coverage in SSA, which can partly be explained by the fact that children in SSA are most often vaccinated in the form of itinerant vaccination campaigns.[43] Vaccination campaigns are organised by health authorities, who deploy health workers for outreach to remote areas by road and in motorised vehicles.[43 45] These personnel administer vaccines in public locations in small towns and villages, or from home to home (eg, polio). It is typically the case that larger countries have the most inaccessible localities for these vaccination campaigns.[27] This is reflected in the absence of passable roads or very long distances, which can affect vaccination services. Moreover, larger countries commonly have inadequate numbers and distribution of health facilities that are necessary to facilitate vaccination.[27]

Socio-cultural differences between countries may also explain these disparities in FV coverage in SSA. For instance, in Uganda and Northern Nigeria, many parents/caregivers refuse to vaccinate their children because of mistrust and campaign propaganda.[23 46] In Malawi, Nigeria, Kenya and Tanzania, mothers may be pressured by partners (patriarchal societies) to vaccinate or not vaccinate children.[27 47 48] Also, in countries such as Burkina Faso, Cameroon, Chad, Ethiopia, Madagascar and Mali, ethnicity, cultural beliefs (eg, beliefs that vaccines contain harmful ingredients that cause female infertility) and religious beliefs are a barrier to full childhood vaccination coverage.[49–51] Many parents/caregivers believe in the efficacy of traditional medicines.[52]

COVID-19 has negatively affected childhood vaccination coverage in Madagascar (48.5% in 2021 vs 61.6% in 2009) and Burkina Faso (71.5% in 2021 vs 81.3% in 2010) because of restrictions on movement and disruptions to essential health services during the pandemic.[53 54] Parents/caregivers were afraid to visit health centres to avoid contracting the infection.[53] Besides, logistical barriers and measures to mitigate the risk of COVID-19 transmission have adversely affected house-to-house campaigns and community-based programmatic efforts.[54]

Socio-demographic factors associated with FV coverage in SSA countries

Consistent with previous studies,[45 55] maternal age was a predictor of FV; mothers aged 25–34 and 35–44 were more likely to have fully vaccinated children than those under 25. This can be attributed to older women's greater

use of maternal health services. Therefore, they would have a better knowledge of childhood diseases that can be prevented by basic vaccinations.[45]

The educational status of mothers was associated with FV coverage, which is supported by studies in India[17] and Turkey.[56] The more educated the mother, the better access she would have to health information and resources, as well as better understanding of the benefits of childhood vaccination services.[18 29] Furthermore, educated mothers influence the repressive attitudes of hesitant partners towards vaccines.[18] Besides, educated mothers have greater autonomy in healthcare decisions when accessing child healthcare services.[45]

Household size was also a determinant of FV. Children from households with more than five members had higher odds of FV compared with children from households with fewer members. A study in Brazil has reported similar findings.[19] Mothers from large households are more likely to receive support from other members of the household, which may positively affect their ability to better care for their children and afford them the time they have to take eligible children for vaccination.[20]

Birth order was inversely correlated with FV. The odds of FV increased with a decrease in the number of children a mother has had. This finding aligns with a study conducted in Pakistan[21] and probably reflects different factors. First, it is well established that women go to the health centres more during their first pregnancy/birth because of their greater vulnerability (they are more likely to be overweight, obese and suffer from high blood pressure than their cadets).[22] Second, some researchers argue that they do not make the same investment in health inputs, such as vaccination for children of higher birth orders than their elderly siblings.[57] Third, a high number of children could significantly impact a family's resources, which would decrease their odds of FV.[18]

Children from wealthier households were more likely to be FV than those from poor households. Similarly, mothers with an income-generating activity were more likely to fully vaccinate their children compared with those without income-generating activity. Earlier studies have reported similar findings.[18 43 45] Economically vulnerable mothers face greater difficulties in covering the indirect costs of accessing maternal and child health services (transportation, vaccination card).[43] In parallel, our data showed that mothers from poor households were better educated than those from poor households. Notably, educated mothers in SSA tend to have better healthcare-seeking behaviour.[45]

Compared with children delivered at home, children delivered in health facilities were more likely to be fully vaccinated. Likewise, mothers who received at least four antenatal visits during pregnancy had higher odds of fully vaccinating their children than mothers who reported fewer than four visits. These findings are in line with studies conducted in Brazil,[58] Indonesia,[59] Pakistan[21] and Somalia.[60] Contact with health professionals enables mothers to discuss and obtain reliable information about vaccinating their children and ensures prompt delivery of vaccines administered at birth.[29] It also gives healthcare providers the opportunity to raise parents' awareness of childhood immunisation and review vaccination histories, resulting in a significant reduction in missed opportunities and better monitoring of children's vaccination schedules.[18 43 45]

Having divorced/separated/widowed mothers was associated with a decreased likelihood of FV. A similar result was found in Somalia.[61] In SSA, divorced/separated/widowed mothers live in very precarious conditions and generally receive no support from their ex-partner or family.[18] In many countries in this region, they are even marginalised.[62] As a result, they would have few financial resources to cover the indirect costs of vaccinating their children and face time constraints as they have to scramble to care for their children.[18 27]

Strengths and limitations of the study

The strengths of our study lie in the use of the latest nationally representative DHS, conducted in 34 SSA countries between 2012 and 2023. DHS uses standard procedures and validated questionnaires, designed to enable comparison at national and regional levels. Further, the data sets from these 34 countries were merged and weighted, giving reliable regional, subregional and country-level estimates. Further, rigorous analytical procedures were used to minimise sampling errors and obtain representative results for the region, subregions and individual countries included in the study. This study, however, is not without limitations. First, data were not collected simultaneously in all countries, which may introduce some bias in estimates and comparisons at subregional and country levels. Second, we used an exclusively quantitative research design. Future qualitative studies will provide a more nuanced understanding of the FV in SSA. Third, due to the cross-sectional study design, we could not infer causality in the relationships between the exposure variables and the outcome. Fourth, due to the self-reported nature of the DHS, the data may be subject to recall bias that may overestimate/underestimate the findings. This recall bias may have been mitigated using vaccination cards to collect data on immunisation status. Finally, the use of secondary data has limited the inclusion of other important variables that could have influenced the study findings. For instance, there was no information on the behaviour of health professionals towards mothers/caregivers in child immunisation services.

CONCLUSION

Results of this study highlight an overall low prevalence of FV coverage and inequities in this coverage across subregions and countries in SSA. Despite the benefits of immunisation through deaths averted over the last five decades since the EPI was established, difficulties in access and utilisation of these critical services continue to threaten child survival in countries with low vaccination

coverage. Therefore, multifaceted efforts must be expedited to quickly scale up coverage with all vaccines across SSA, especially in West and Central African countries.

Although 'The Big Catch-up' initiative of GAVI[12] is a laudable step towards closing accelerating progress towards the targets of the 2030 Immunization Agenda, this programme must be promptly customised and adopted by each SSA country to adequately address the access and utilisation barriers to vaccination uptake. Indeed, individual country governments and all partners must also implement contextually appropriate actions to rapidly scale up immunisation services to reach underimmunised and unimmunised children in their respective jurisdictions. Some cross-cutting actions may include increased and sustained funding for vaccination programmes and supplies, training and support for vaccination providers, strengthening the primary healthcare infrastructure and data monitoring and surveillance. Taken together, country governments, partners and multilateral agencies must make more concerted efforts to deliver vaccination services to promote child health and well-being in SSA.

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