BMJ Open

Subnational trends and inequalities of under-immunisation and zero-dose among children aged 12–23 months in Uganda: a national population-based cross-sectional study

Ronald Wasswa ,[1,2] Rornald Muhumuza Kananura,[2,3] Peter Waiswa,[1,2,4,5] Jennifer Harris Requejo,[6,7] Thiago M Santos ,[8] Aluisio J D Barros [8]

To cite: Wasswa R, Kananura RM, Waiswa P, *et al*. Subnational trends and inequalities of under-immunisation and zero-dose among children aged 12–23 months in Uganda: a national population-based cross-sectional study. *BMJ Open* 2025;**15**:e093619. doi:10.1136/bmjopen-2024-093619

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2024-093619).

Received 11 September 2024
Accepted 29 November 2024

Check for updates

© Author(s) (or their employer(s)) 2025. Re-use permitted under CC BY. Published by BMJ Group.

For numbered affiliations see end of article.

Correspondence to
Mr Ronald Wasswa;
rwasswa93@yahoo.com

ABSTRACT

Objective Despite the Global Vaccine Action Plan's goal of at least 90% vaccine coverage for all children, Uganda has made limited progress in vaccination over the past decade. The objective of this study was to examine the subnational trends in the prevalence and inequalities in under-immunisation and zero-dose among children aged 12–23 months in Uganda.

Study design A retrospective national cross-sectional study.

Setting Uganda

Participants Uganda Demographic and Health Survey secondary data of only children aged 12–23 months. The samples selected for analyses were 1507 in 2006, 1409 in 2011 and 2650 children in 2016.

Outcome measure The primary outcomes were under-immunisation and zero-dose vaccination.

Absolute and relative inequality measures were used in the analysis.

Results From 2006 to 2016, the under-vaccination rate decreased by 21%, but remained high at 40.8%. The zero-dose vaccination rate dropped by 82%, affecting 1.2% of children in 2016. Subnational inequalities in under-vaccination increased over time with widening gaps between regions. While inequalities across wealth quintiles, maternal education levels and places of residence narrowed, children of mothers with lower education levels continued to have the highest under-vaccination rates. The rural–urban gap for zero-dose vaccination remained unchanged, with rural children disproportionately impacted.

Conclusion While some progress was made in reducing under-vaccination rates in Uganda within the study period, no region achieved an under-vaccination rate below 20%. This indicates significant challenges in reaching the Sustainable Development Goal target of at least 80% immunisation coverage. Targeted interventions are necessary to improve healthcare access, enhance public health communication and strengthen the health system, particularly in underserved communities and among vulnerable populations.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study uses data from three reliable and nationally representative Uganda Demographic and Health Surveys.
⇒ It examines subnational inequalities in under-immunisation and zero-dose vaccination, revealing disparities masked by national averages.
⇒ It employs both absolute and relative inequality measures for a comprehensive regional and socioeconomic assessment.
⇒ We also acknowledge potential recall bias that may have affected the accuracy of vaccination data due to reliance on mothers' memory in the absence of the vaccination card.
⇒ The most recent available data is from 2016, which may not fully reflect the current situation, and the cross-sectional design limits the ability to draw causal inferences.

INTRODUCTION

Immunisation is one of the most powerful and cost-effective interventions for preventing diseases.[1–6] Over a span of 20 years, vaccines have averted 36 million deaths of children under 5 in low- and middle-income countries, with an additional 28 million projected to be averted by 2030.[7] Recognising these benefits, the World Health Assembly endorsed the Global Vaccine Action Plan (GVAP), aiming for universal access to immunisation for every child by 2030.[8] The GVAP set targets of at least 90% coverage at the national level, with no subnational region with a coverage of less than 80% for all routine immunisation vaccines by 2030.[8–10] Similarly, the Immunization Agenda 2030 also aims to ensure full immunisation for every child, regardless of location, age, socioeconomic status or gender-related barriers.[8–10]

Despite tremendous progress in vaccination coverage, a significant proportion of children remain unvaccinated or under-vaccinated, particularly in sub-Saharan Africa. For

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

instance, in 2022, there were an estimated 14.3 million unvaccinated children (zero-dose children), with an additional 6.2 million partially vaccinated, the majority of whom reside in sub-Saharan Africa.[11] In Uganda, national coverage for full basic vaccination among children aged 12–23 months has seen slow progress over the past decade, reaching 55% in 2016.[12] Regional inequalities in routine vaccination coverage persist despite initiatives like the Reaching Every District initiative introduced in 2004 to increase coverage and equity in immunisation across communities.[13–15] Despite efforts from programmes like the Uganda National Expanded Program on Immunization and the Maternal and Child Health Integrated Program, Uganda still has a substantial number of zero-dose children.[12]

Detailed subnational trends in immunisation coverage remain unclear in Uganda due to changes in the subregional groupings in the successive demographic health surveys. This lack of clarity in subregions limits efforts to address regional inequities effectively. While studies in sub-Saharan Africa, including Uganda, have examined factors associated with immunisation coverage, limited information exists on subnational inequalities in Uganda to inform targeted interventions.[16–24] Therefore, this study examined subnational trends in the prevalence and inequalities in under-immunisation and zero-dose among children aged 12–23 months in Uganda. By understanding these trends and disparities, targeted interventions can be developed to improve immunisation coverage and reduce regional inequalities.

METHODS

Data source, acquisition and population

This study used data from three consecutive Uganda Demographic and Health Surveys (UDHSs) conducted in 2006, 2011 and 2016. Approval to download and use these deidentified datasets was obtained from the Measure DHS website (www.measuredhs.com) on request, ensuring ethical compliance for secondary data use.[25] Each UDHS is nationally representative and employs a two-stage cluster sampling design. In the first stage, clusters are selected from a national sampling frame, while in the second stage, households are systematically sampled within each cluster. Detailed information on the sampling methodology and the standardised tools can be found in the UDHS final reports.[12 26 27]

For this study, we focused on children aged 12–23 months, including 1507, 1409 and 2650 children in 2006, 2011, and 2016, respectively. The UDHS collects data at both household and individual levels, covering a wide range of health and demographic indicators, including immunisation, maternal and child health and nutrition.

Data curation

On obtaining the datasets[25] we conducted a thorough data-curation process to ensure readiness for analysis. This involved extracting and filtering data specifically for children aged 12–23 months and immunisation indicators, along with additional variables on household and maternal characteristics. We addressed missing or implausible values through data cleaning. To ensure consistency and comparability across survey years, all study variables were standardised. A data dictionary was generated to document all transformations, recoding decisions and data-cleaning steps.

Harmonisation of subnational boundaries

Demographic health surveys serve as a crucial tool for providing reliable estimates of survey indicators at both the national and subnational levels.[12 26 27] However, Uganda has experienced changes in the number of subregions in each successive survey, which limits their comparability over time. With the pressing need to achieve the Sustainable Development Goals (SDGs), there is a growing demand to understand subnational patterns for informed decision-making and efficient programme implementation. To address this, we reconstructed the subregions in the 2016 and 2011 surveys to align with the nine subregions included in 2006. This alignment was accomplished using a methodology[28 29] that leveraged the Integrated Public Use Microdata Series (IPUMS)- International geographical data files[30] and the DHS Spatial Repository[31] to harmonise the subregional boundaries across surveys. The IPUMS-DHS project specifically supports harmonisation by providing consistently coded variables, cross-survey documentation and customisable datasets that enhance comparability over time. Our approach included assigning a standardised identifier to each harmonised subregion, checking the consistency of area boundaries across surveys and ensuring that the geographical structure aligns with the 2006 baseline. This process enables reliable trend analysis at the subnational level. Additional details of the harmonisation process have been documented elsewhere.[28 29 32]

Selection and measurement of variables

Outcomes

Our study focused on two key indicators: under-vaccination and zero-dose vaccination, which were estimated from data collected through interviews with mothers regarding their children's vaccination status. Under-vaccination was defined as a child not receiving all the following vaccine doses: one dose of BCG, three doses of polio, three doses of pentavalent and one dose of a measles-containing vaccine. Zero-dose was defined as a child not receiving a single dose of any of the above vaccines. The child's vaccination card is the primary source of data collected through household surveys on the vaccines administered and the number of doses. If a vaccination card is unavailable, survey interviewers ask caretakers/mothers about their children's vaccination history, the vaccines administered and the number of doses received. When mothers could not recall their child's vaccination status, the child was categorised as non-vaccinated for that specific vaccine.

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

Table 1 Selected summary measures of inequality in under-vaccination rates

Summary measure	Measure type	Description	Formula
Difference	Simple measure of absolute inequality	The difference between the indicator value for a category (y_{high}) with the highest under-vaccination rate, and the value of the category (y_{low}), with the lowest under-vaccination rate	$y_{high} - y_{low}$
Weighted mean absolute difference from the overall mean (WMADM)	Complex measure of absolute inequality	The weighted average of the difference between the under-vaccination rate for subregion j (y_j), and the national average (μ), Differences are weighted by each subregion's share of the total population (pop_j),	$\frac{\sum_j pop_j \times \lvert y_j - \mu \rvert}{pop}$
Ratio	Simple measure of relative inequality	The ratio of the category with the highest under-vaccination rate ($y_{(high)}$) to the category with the lowest undervaccination rate ($y_{(low)}$).	$\frac{y_{(high)}}{y_{(low)}}$
Weighted mean relative difference from the overall mean (WMRDM)	Complex measure of relative inequality	The weighted average of the difference between the indicator value for subregion j (yj) and the national average (μ) divided by the national average (μ) and multiplied by 100. Differences are weighted by each subregion's share of the total population (pj)	$\frac{WMADM}{\mu} \times 100$

Equity stratifiers

Four key equity stratifiers were used to disaggregate under-vaccination and zero-dose vaccination: subnational regions, maternal education level, wealth quintiles and place of residence. These variables were selected based on their significance in prior research[33 34] and their inclusion in the WHO Health Inequality Monitoring Handbook.[35] The UDHS employs principal component analyses on various household assets, dwelling characteristics and access to basic amenities to generate a wealth index, which is categorised into five equally sized groups, the quintiles, ranging from poorest to richest.[36] Maternal education levels were classified as none, primary and secondary or higher, while place of residence was categorised as urban or rural. Additionally, the nine harmonised subnational regions were used.

Statistical analysis

The data were weighted using the sample weight variable from the DHS to ensure representativeness, and the weighting variable was applied in all statistical analyses.[12 26 27] In the analysis, we began by disaggregating the proportions of under-vaccination and zero-dose vaccination across the four equity stratifiers. Subsequently, four inequality summary measures were employed, detailed in table 1. These measures included both absolute and relative metrics, such as absolute difference, weighted mean absolute difference from the overall mean, ratio and weighted mean ratio from the overall mean. This methodological approach aligns with previous studies.[37 38]

Hosseinpoor and colleagues[37] highlighted that simple measures of inequality, such as differences and ratios, often yield findings comparable to those of more complex measures. In our analysis, differences and ratios, effectively revealed disparities between the best-performing and worst-performing subregions, while complex measures provided additional details by accounting for variations between each subregion and the national average, weighted by population size. This similarity between simple and complex measures strengthens the validity of our results and highlights the urgency of addressing the identified inequities and gaps in health coverage.

Patient and public involvement

As this study used secondary data, there was no direct involvement of patients or the public in the study design, data collection or analysis processes.

RESULTS

Table 2 presents the distribution of the study population across selected equity stratifiers for the years 2006, 2011 and 2016. The household wealth index shows a consistent representation across all categories each comprising roughly 14.0–24.0% of the population. Maternal education levels indicate that the majority of the children had mothers with at least primary education (61.4–65.7%), followed by secondary or higher education (13.7–29.4%). Results also indicate that children in urban areas constituted 9.6–22.7% of the child population, while rural children ranged between 77.3–90.4% for the entire study period. The distribution of children across regions is fairly even, with the largest population shares in the Eastern (17.0–17.4%) and Western (13.1–15.1%) regions.

Figure 1 shows the trends in under-vaccination and zero-dose vaccination for the period of 10 years. The prevalence of undervaccinated children reduced by 21%, from 51.8% in 2006 to 40.8% in 2016. In the same period, the percentage of zero-dose children reduced by 82%, from 6.7% to 1.2%.

The trends in under-vaccination rates for children (figure 2) show a significant improvement across subregions from 2006 to 2016. The Southwest region experienced the largest reduction, with a 22 percentage point decrease, followed closely by West Nile with a 21 percentage point reduction. The Busoga and Western regions experienced the smallest decline of 7 and 4 percentage points, respectively. In contrast, the North Buganda region's under-vaccination rate remained stagnant.

Results also show a substantial decrease in the prevalence of zero-dose children across subregions. The South Buganda region had the most notable improvement, with a decline from 17.6% in 2006 to 2.5% in 2016. This was followed by North Buganda and Southwest region

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

Table 2 Distribution of the study population by the selected stratifiers

Equity stratifier	2006 (n=1507) n (%)	2011 (n=1409) n (%)	2016 (n=2650) n (%)
Wealth index			
Lowest	320 (21.2)	317 (22.5)	586 (22.1)
Second	360 (23.9)	309 (21.9)	577 (21.8)
Middle	331 (22.0)	258 (18.3)	497 (18.7)
Higher	285 (18.9)	261 (18.5)	457 (17.2)
Highest	211 (14.0)	264 (18.7)	534 (20.2)
Maternal education			
No education	310 (20.6)	184 (13.1)	242 (9.1)
Primary	990 (65.7)	892 (63.3)	1628 (61.4)
Secondary or higher	207 (13.7)	332 (23.6)	780 (29.4)
Place of residence			
Urban	144 (9.6)	189 (13.4)	602 (22.7)
Rural	1363 (90.4)	1220 (86.6)	2049 (77.3)
Region			
South Buganda	150 (9.9)	146 (10.3)	329 (12.4)
North Buganda	123 (8.2)	156 (11.1)	282 (10.6)
Kampala	66 (4.3)	78 (5.6)	122 (4.6)
Busoga	174 (11.6)	162 (11.5)	276 (10.4)
Eastern	256 (17.0)	244 (17.3)	462 (17.4)
North	250 (16.6)	197 (14.0)	339 (12.8)
West Nile	81 (5.3)	74 (5.3)	195 (7.4)
Western	228 (15.1)	184 (13.1)	366 (13.8)
Southwest	181 (12.0)	168 (11.9)	280 (10.6)

n is the frequency; % is the percentage; all results based on weighted data.

with each experiencing a decline of 9 percentage points (figure 2).

However, despite these positive changes, there was a significant increase in subnational inequality in under-vaccination rates. The weighted mean relative difference in weighted mean ratio from the overall mean rose from 4.6 in 2006 to 14.5 in 2016, accompanied by an increase in the ratio and weighted mean absolute difference from the overall mean (figure 3). The gap between the national prevalence and the prevalence in the best-performing region also widened, increasing from 1.14 in 2006 to 1.32 in 2016 (figure 3).

Results further revealed that inequality in under-vaccination rates also varied by place of residence, maternal education and wealth index from 2006 to 2016. In relation to household wealth, the prevalence of under-immunisation decreased across all quintiles. In 2006, undervaccination among the poorest was 57.2%, falling to 41.3% by 2016, and for the richest, it decreased from 51.4% to 40.5% (figure 4). In addition, the absolute difference in wealth index inequality reduced from 9.4 percentage points in 2006 to 4.4 percentage points in 2016 (online supplemental file 1).

Children of mothers with no education or primary education consistently had higher under-vaccination rates compared with those with secondary or higher education levels. In 2006, under-vaccination for children of mothers with no education was 59.2%, dropping to 42.3% by 2016, while for those with secondary or higher education, under-vaccination decreased from 40.7% to 37.0% (figure 4). In addition, the absolute difference sharply dropped from 18.5 percentage points in 2006 to 5.4 percentage points in 2016 (online supplemental file 1).

The prevalence of under-vaccination in rural areas decreased from 52.2% to 40.6%, and in urban areas from 48.2% to 41.6% by 2016. Place of residence inequality also diminished, with the absolute difference between urban

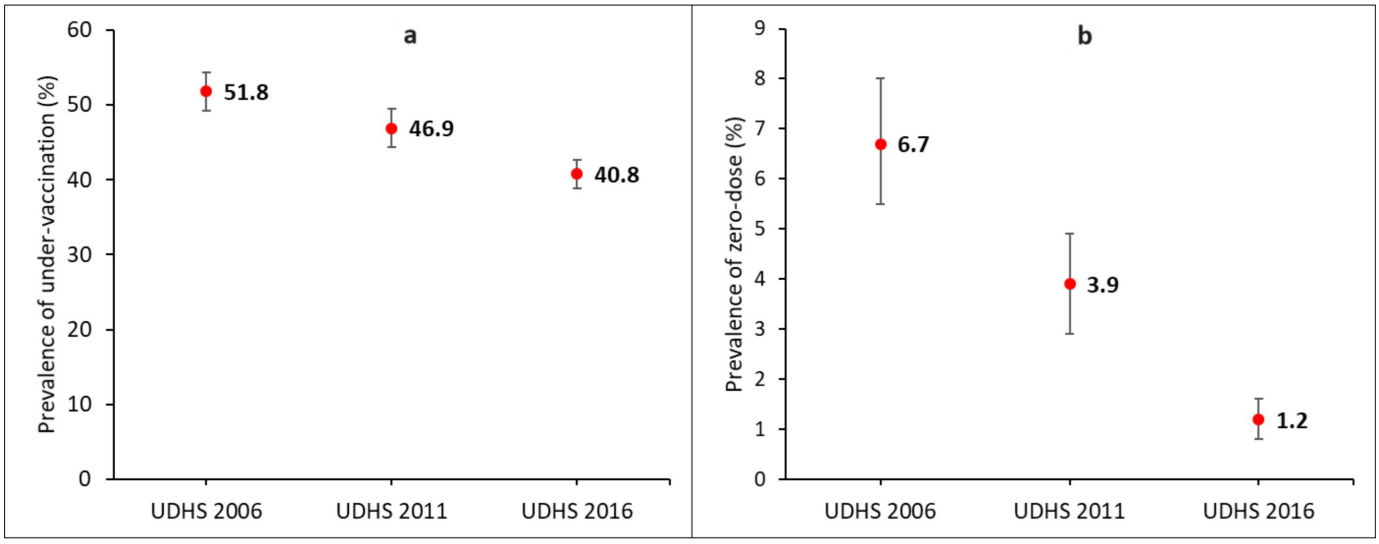


Figure 1 National trends in under-vaccination (a), and zero-dose vaccination (b) in Uganda. Bars represent 95% CI.

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

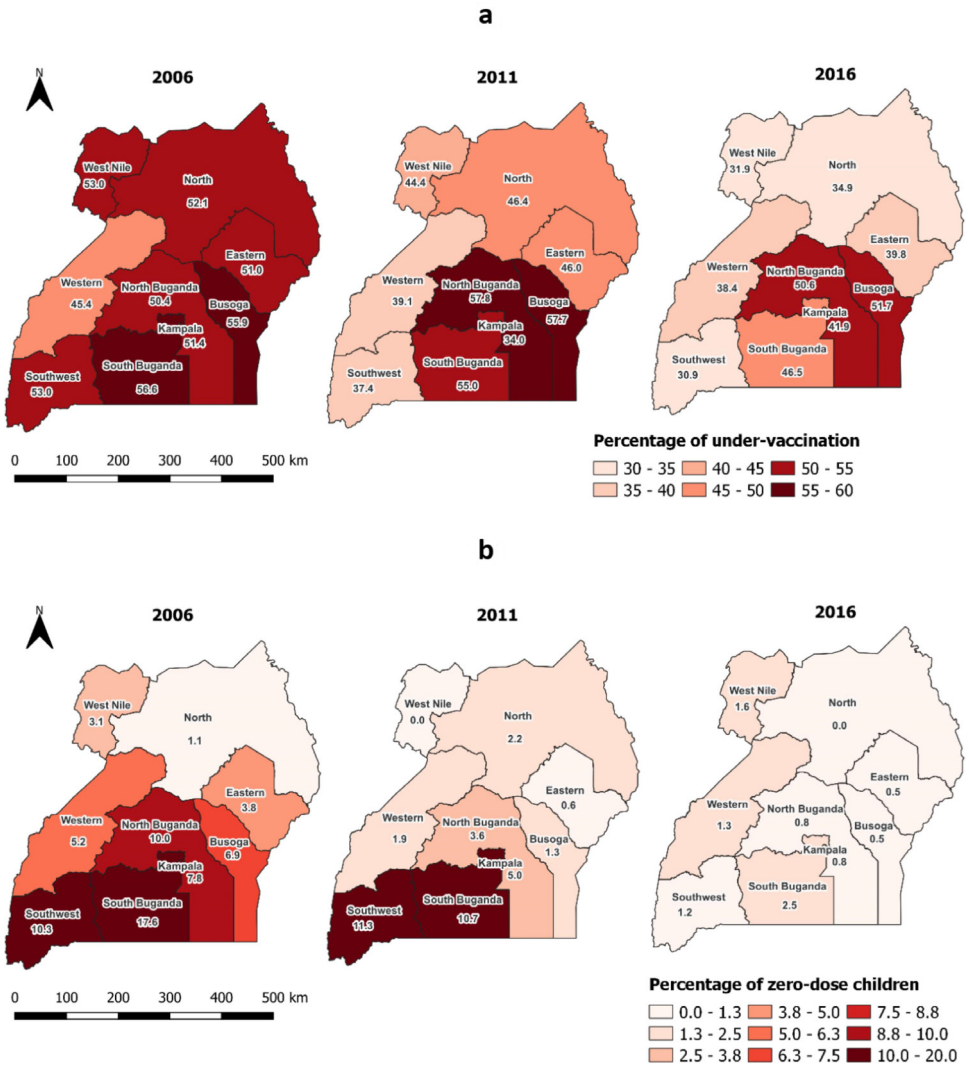


Figure 2 Subnational trends in under-vaccination (a) and zero-dose children (b) in Uganda.

and rural areas dropping from 4.0 percentage points in 2006 to 1.0 percentage point in 2016 (online supplemental file 1). This suggests a narrowing rural–urban inequality gap despite the persistently high prevalence of undervaccination.

Findings also showed that from 2006 to 2016, the prevalence of zero-dose children consistently declined across all stratifiers, despite persistent inequalities among the less privileged (online supplemental file 1). Among the poorest households, the zero-dose rate dropped from 3.8% to 1.4%, while among the richest households, it declined from 7.3% to 0.2%. The lowest prevalence was among children whose mothers had higher education levels, with rates decreasing from 8.0% to 2.6% among mothers with no education, and from 3.5% to 0.3% among those with secondary or higher education. Similarly, the prevalence in rural areas reduced from 6.8% to 1.4%, and in urban areas from 5.8% to 0.5% (online supplemental file 1).

DISCUSSION

In line with earlier findings[39] our results indicate that Uganda has experienced a substantial decrease in zero-dose vaccination rates over the study years and a slight reduction in under-vaccination rates across its regions. However, none of the regions achieved an under-vaccination rate below 20% by the end of the study period, indicating challenges in reaching the SDG target of at least 80% immunisation coverage.[8–10] In addition, our findings align with those of Ssebagereka and colleagues[39] to highlight the significant role of socioeconomic factors and regional disparities in influencing vaccine coverage. We noted a widening subregional inequality, with under-vaccination rates diverging over time.

There is a noticeable disparity between the national prevalence of under-vaccination and the prevalence in the best-performing region, highlighting growing inequities across Uganda between 2006 and 2016. While some regions showed progress in reducing under-vaccination rates, the national rate increased at a faster pace, highlighting a concerning trend where national efforts are not resulting in equal advancements across all regions. Particularly, North Buganda and Busoga exhibit little or stagnant progress over the study decade in regard to under-vaccination. These disparities may stem from

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

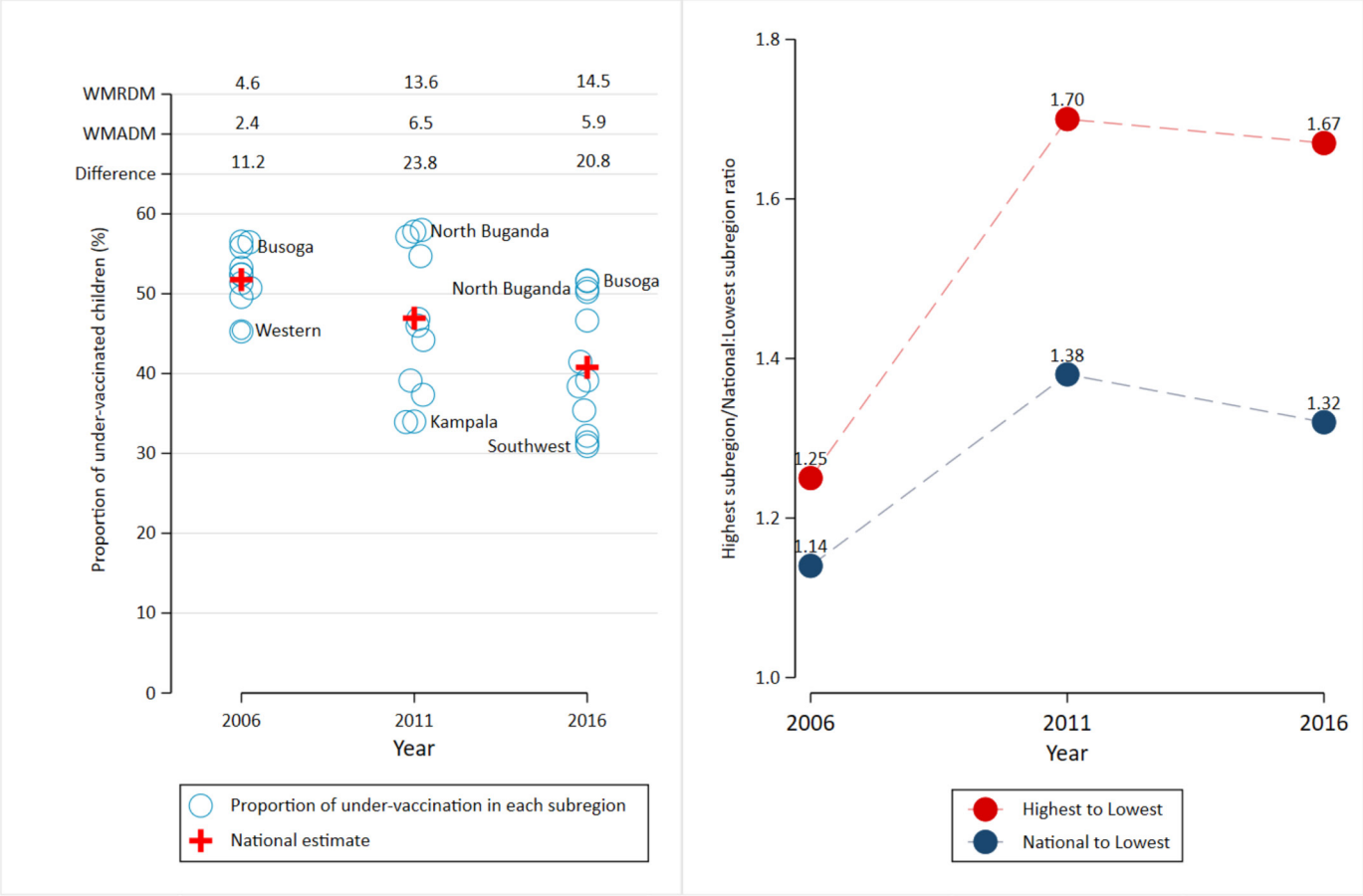


Figure 3 Subnational inequality gap in the prevalence of under-vaccination. WMADM, weighted mean absolute difference from the overall mean; WMRDM, weighted mean relative difference from the overall mean.

differences in socioeconomic status, resource allocation to the health sector and other health system barriers such as a disrupted cold chain, irregular vaccine supplies and distribution, limited healthcare personnel and infrastructure and significant distances between health facilities and communities.[40–48]

Consistent with earlier studies conducted in sub-Saharan Africa,[49–51] our study found a significant reduction in rural–urban inequalities in under-immunisation over time. Despite this positive trend, the prevalence of under-vaccination remained high among both urban and rural children, indicating that while disparities have narrowed, overall vaccination coverage still lags behind expectations. However, in contrast to the trend observed for under-immunisation, the rural–urban gap in zero-dose vaccinations did not show a comparable reduction. Rural children continued to bear a disproportionate burden of zero-dose vaccination compared with their urban counterparts. This finding contrasts with Ssebagereka *et al*'s study, which reported a narrowing of urban–rural disparities in zero-dose vaccinations over a similar period.[39] Several factors may explain this divergence. First, the definition of zero-dose vaccinations slightly differs between the studies: Ssebagereka *et al* define zero-dose as a child who has not received any doses from the national immunisation schedule by 12 months of age, whereas in our study, we considered children who had not received any vaccines within the 12–23 month age range. Additionally, differences in methodology such as the inequality measures employed and our approach to harmonise subnational boundaries across different survey years may have influenced the interpretation of trends over time, contributing to the contrasting findings.

One possible explanation for the persistent inequality in zero-dose vaccinations as noted in this study is the proximity to health facilities. Urban children generally live closer to healthcare services than rural children, making it easier for caretakers to access vaccination services.[52] We hypothesise that the high prevalence of under-vaccination in urban areas may be significantly influenced by disparities between non-poor and poor urban children. Santos and colleagues revealed that non-poor urban children have an advantage in terms of immunisation compared with their poorer counterparts.[52 53] In some cases, urban poor children may even have worse immunisation outcomes than rural children.[52] Addressing these issues requires targeted interventions to improve healthcare access among the urban poor, enhance public health communication about the benefits of vaccination and strengthen the health system to better serve all vulnerable populations.

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.



Figure 4 Inequality in the percentage of under-vaccination: by wealth (a), maternal education (b), and place of residence (c).

Disparities based on household wealth significantly decreased by 2016, indicating narrowing inequalities in access to immunisation services among different socioeconomic groups. This was evidenced by the decline in absolute disparity measures, reflecting a narrower gap between wealthy and poor households. While previous studies have shown lower access to healthcare services among the economically disadvantaged,[40 41 47 53–57] our findings show a more rapid improvement in immunisation coverage among children in the poorest quintile compared with those in the wealthiest. Uganda ranks highly among the global leaders in implementing pro-equity immunisation efforts, with over 38 strategies addressing both demand and supply challenges.[39 58] These initiatives have played a significant role in narrowing immunisation equity gaps. Similar approaches have also been shown to reduce disparities in healthcare access and use elsewhere.[59 60]

Our findings showed that children of mothers with lower education levels experience higher rates of under vaccination. This finding aligns with earlier studies, reaffirming the correlation between maternal education and vaccination status among children.[39–41 47 54 55 61] Additionally, the inequality gap between the educated and illiterate has narrowed, but the under-vaccination rate for children of mothers with secondary and higher education remained largely unchanged during the study period. While the percentage of educated mothers increased over time, their children's vaccination rates did not show significant improvement. This suggests that merely increasing maternal education levels may not sufficiently enhance vaccination rates. Implementing targeted outreach programmes for communities with lower maternal education levels, focusing on tailored education, community engagement with local leaders and health workers and strengthening health systems will enhance vaccination access and acceptance.

This study leverages data from three reliable and nationally representative UDHS to examine subnational inequalities in under-immunisation and zero-dose vaccination, revealing disparities often masked by national averages. By employing both absolute and relative inequality measures, it provides a comprehensive assessment across regions and socioeconomic groups. However, limitations include potential recall bias from mothers' reports in the absence of vaccination cards, the use of data from 2016 that may not reflect the current immunisation landscape and the cross-sectional nature of the data which limits causal inferences.

CONCLUSION

Despite some progress in reducing under-vaccination rates in Uganda, the country still faces significant challenges in achieving the SDG of 80% immunisation coverage. The analysis reveals widening subregional inequalities, with some regions showing little or no progress in reducing under-vaccination rates. Rural areas continue to bear a disproportionate burden, with urban–rural disparities persisting, particularly in zero-dose vaccinations. Socioeconomic inequalities also persist, with children of

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

lower-income and less-educated mothers being disproportionately affected.

To address these issues, targeted interventions are needed to improve healthcare access, public health communication and health system strengthening, particularly in underserved communities and among vulnerable populations. Additionally, further detailed studies could explore locally important underlying causes of these disparities, while the implementation of evidence-based strategies to optimise vaccine acceptance is evaluated in partnership with local communities, health professionals and authorities. Combining targeted research with collaborative, community-driven solutions can help achieve more equitable vaccination coverage across Uganda.

Author affiliations
[1]Department of Health Policy Planning and Management, Makerere University School of Public Health, Kampala, Uganda
[2]Makerere University Center of Excellence for Maternal and Newborn Health, Kampala, Uganda
[3]African Population and Health Research Center (APHRC), Nairobi, Kenya
[4]Global Public Health, Karolinska Institutet, Stockholm, Sweden
[5]Busoga Health Forum, Jinja, Uganda
[6]Global Financing Facility for Women, Children, and Adolescents, World Bank, Washington, DC, USA
[7]Department of International Health, Johns Hopkins University, Baltimore, Maryland, USA
[8]International Center for Equity in Health, Universidade Federal de Pelotas, Pelotas, Brazil

X Ronald Wasswa @rwasswa93 and Aluisio J D Barros @AluisioJDBarros

Acknowledgements We express our gratitude to the Demographic and Health Survey Program for granting us access to the dataset used in this study. We also extend our appreciation to all the facilitators from the African Population and Health Research Center and the CD2030 Global Experts from the CD2030 Data Analysis Centres and collaborating universities who facilitated the training workshop attended by the corresponding author.

Contributors RW, RMK, PW, JHR and AJDB conceptualised the study and designed the methodology. RW led the statistical analysis, interpretation of the results and prepared the first draft of the manuscript with the guidance of RMK, PW, JHR and AJDB . RMK, PW, JHR, TMS and AJDB conducted the initial review and provided critical interpretation of the analyses. All authors, including RW, RMK, PW, JHR, TMS and AJDB, discussed the study findings, participated in the critical revision of the manuscript and contributed to its intellectual improvement. Finally, all authors reviewed and designed the final manuscript. RW is the guarantor.

Funding This research was [partially] funded by the Bill and Melinda Gates Foundation through a grant to APHRC (grant number INV-003416 - Countdown to 2030).

Map disclaimer The inclusion of any map (including the depiction of any boundaries therein), or of any geographical or locational reference, does not imply the expression of any opinion whatsoever on the part of BMJ concerning the legal status of any country, territory, jurisdiction or area or of its authorities. Any such expression remains solely that of the relevant source and is not endorsed by BMJ. Maps are provided without any warranty of any kind, either express or implied.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study used secondary data which is freely available online. The authors accessed the UDHS data by receiving permission through DHS measure online (http://dhsprogram.com/). 16 Procedures and questionnaires for standard DHS surveys have been reviewed and approved by ICF Institutional Review Board (IRB). Additionally, UDHS survey protocols were reviewed by the ICF IRB and by an IRB in Uganda. ICF IRB ensures that the survey complies with the U.S. Department of Health and Human Services regulations for the protection of human subjects (45 CFR 46), while the IRB-Uganda ensures that the survey complies with laws and norms of the nation. The study was therefore exempted from collecting ethical approval.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. All the datasets used for this study were from the Demographic and Health surveys (DHS) and available here: http://dhsprogram.com/data/available-datasets.cfm.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution 4.0 Unported (CC BY 4.0) license, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made. See: https://creativecommons.org/licenses/by/4.0/.

ORCID iDs
Ronald Wasswa http://orcid.org/0000-0003-1251-2460
Thiago M Santos http://orcid.org/0000-0002-4572-5297
Aluisio J D Barros http://orcid.org/0000-0002-2022-8729

REFERENCES

1 Lee LA, Franzel L, Atwell J, *et al*. The estimated mortality impact of vaccinations forecast to be administered during 2011–2020 in 73 countries supported by the GAVI Alliance. *Vaccine (Auckl)* 2013;31:B61–72.
2 Andre FE, Booy R, Bock HL, *et al*. Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bull World Health Organ* 2008;86:140–6.
3 Ozawa S, Mirelman A, Stack ML, *et al*. Cost-effectiveness and economic benefits of vaccines in low- and middle-income countries: A systematic review. *Vaccine (Auckl)* 2012;31:96–108.
4 Ozawa S, Clark S, Portnoy A, *et al*. Return On Investment From Childhood Immunization In Low- And Middle-Income Countries, 2011-20. *Health Aff (Millwood)* 2016;35:199–207.
5 UNICEF. Immunization: vaccines are the world's safest method to protect children from life-threatening diseases. Available: https://www.unicef.org/immunization [Accessed 22 Nov 2022].
6 Henderson RH. The Expanded Programme on Immunization of the World Health Organization Author (s): Ralph H. Henderson Source: Reviews of Infectious Diseases.International Symposium on Poliomyelitis Control. *Rev Infect Dis* 1984;6:475–9.
7 Li X, Mukandavire C, Cucunubá ZM, *et al*. Estimating the health impact of vaccination against ten pathogens in 98 low-income and middle-income countries from 2000 to 2030: a modelling study. *Lancet* 2021;397:398–408.
8 World Health Organization. Global vaccine action plan 2011-2020. 2011.
9 World Health Organization. Strategic advisory group of experts on immunization. the global vaccine action plan 2011-2020. Review and Lessons Learned; Geneva, 2019.
10 WHO. 2018 assessment report of the global vaccine action plan. Geneva Strategic Advisory Group of Experts on Immunization; 2018.
11 WHO. Immunization coverage. Available: https://www.who.int/news-room/fact-sheets/detail/immunization-coverage [Accessed 22 Mar 2024].
12 Uganda Bureau of Statistics (UBOS) and ICF. Uganda demographic and health survey 2016. Kampala, Uganda and Rockville, Maryland, USA, 2018.
13 USAID Maternal and Child Survival Program. End of Project Report Uganda Routine Immunization Program. 2019.
14 What is reaching every district (RED) in immunization?: a brief overview. Available: https://www.comminit.com/unicef/content/what-reaching-every-district-red-immunization-brief-overview [Accessed 24 Nov 2022].

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

15 World health organization. In: *Reaching Every District (RED), 2017 revision*. Brazzaville, 2017.
16 Bbaale E. Factors influencing childhood immunization in Uganda. *J Health Popul Nutr* 2013;31:118–29.
17 Balgovind P, Mohammadnezhad M. Factors affecting childhood immunization: Thematic analysis of parents and healthcare workers' perceptions. *Hum Vaccin Immunother* 2022;18:2137338.
18 Galadima AN, Zulkefli NAM, Said SM, *et al*. Factors influencing childhood immunisation uptake in Africa: a systematic review. *BMC Public Health* 2021;21:1–20.
19 Abdilahi MM, Mohamed AI, Jonah KM, *et al*. Prevalence and factors associated with immunization coverage among children under five years in Mohamed Mooge health center, Hargeisa, Somaliland: a cross-sectional study. *BMC Pediatr* 2023;23:1–8.
20 Jillian O, Kizito O. Socio-Cultural Factors Associated with Incomplete Routine Immunization of Children _ Amach Sub-County, Uganda. *Cog Med* 2020;7.
21 Adedire EB, Ajayi I, Fawole OI, *et al*. Immunisation coverage and its determinants among children aged 12-23 months in Atakumosa-west district, Osun State Nigeria: a cross-sectional study. *BMC Public Health* 2016;16:905.
22 Adedokun ST, Uthman OA, Adekanmbi VT, *et al*. Incomplete childhood immunization in Nigeria: a multilevel analysis of individual and contextual factors. *BMC Public Health* 2017;17:236.
23 Anokye R, Acheampong E, Budu-Ainooson A, *et al*. Socio-demographic determinants of childhood immunization incompletion in Koforidua, Ghana. *BMC Res Notes* 2018;11:656.
24 Simegn W, Diress M, Gela YY, *et al*. Childhood vaccination practices and associated factors among mothers/caregivers in Debre Tabor town, Northwest Ethiopia: A cross-sectional study. *Front Pediatr* 2023;11:1070722.
25 The dhs program - available datasets. Available: https://dhsprogram.com/data/available-datasets.cfm [Accessed 5 Aug 2023].
26 UBOS. Uganda Demographic and Health Survey 2006. Kampala, Uganda and Calverton, Maryland, U*.S.A* 2006.
27 UBOS and ICF International. Uganda demographic and health survey 2011. Kampala, Uganda and Calverton, Maryland, USA; 2011.
28 Belmin C, Hoffmann R, Elkasabi M, *et al*. LivWell: a sub-national Data set on the Living Conditions of Women and their Well-being for 52 Countries. *Sci Data*. 2022;9:1–14. doi:
29 Galeano J, Esteve A, Turu A, *et al*. CORESIDENCE: National and subnational data on household size and composition around the world, 1964–2021. *Sci. Data*. 2024;11.
30 IPUMS-DHS. Available: https://www.idhsdata.org/idhs/ [Accessed 21 Sep 2023].
31 Spatial data repository - boundaries. Available: https://spatialdata.dhsprogram.com/boundaries/#countryId=UG&view=table [Accessed 22 Sep 2023].
32 Boyle EH, King M, Sobek M. IPUMS-demographic and health surveys: version 8. 2019. Available: https://www.ipums.org/projects/ipums-global-health/d080.v8 [Accessed 24 Mar 2024].
33 Bobo FT, Yesuf EA, Woldie M. Inequities in utilization of reproductive and maternal health services in Ethiopia. *Int J Equity Health* 2017;16:105:105:.
34 Yaya S, Zegeye B, Ahinkorah BO, *et al*. Regional variations and socio-economic disparities in neonatal mortality in Angola: A cross-sectional study using demographic and health surveys. *Fam Pract*. 2021;37:785–92. doi:
35 World Health Organization. *Handbook on Health Inequality Monitoring: With a Special Focus on Low- and Middle-Income Countries*. Geneva, Switzerland, 2013.
36 Rutstein SO, Kiersten J. The dhs wealth index. dhs comparative reports no. 6. Calverton, Maryland; 2004.
37 Hosseinpoor AR, Bergen N, Barros AJD, *et al*. Monitoring subnational regional inequalities in health: measurement approaches and challenges. *Int J Equity Health* 2016;15:18.
38 Kirkby K, Bergen N, Schlotheuber A, *et al*. Subnational inequalities in diphtheria–tetanus–pertussis immunization in 24 countries in the african region. *Bull World Health Organ* 2021;99:627–39.
39 Ssebagereka A, de Broucker G, Ekirapa-Kiracho E, *et al*. Equity in vaccine coverage in Uganda from 2000 to 2016: revealing the multifaceted nature of inequity. *BMC Public Health* 2024;2424:1–13.
40 Uthman OA, Adedokun ST, Olukade T, *et al*. Children who have received no routine polio vaccines in Nigeria: Who are they and where do they live? *Hum Vaccin Immunother* 2017;13:2111–22.
41 Wahl B, Gupta M, Erchick DJ, *et al*. Change in full immunization inequalities in Indian children 12–23 months: an analysis of household survey data. *BMC Public Health* 2021;21:1–15.
42 Bangura JB, Xiao S, Qiu D, *et al*. Barriers to childhood immunization in sub-Saharan Africa: A systematic review. *BMC Public Health* 2020;20:1–15.
43 Zewdie A, Letebo M, Mekonnen T. Reasons for defaulting from childhood immunization program: a qualitative study from Hadiya zone, Southern Ethiopia. *BMC Public Health* 2016;16:1240.
44 Cockcroft A, Usman MU, Nyamucherera OF, *et al*. Why children are not vaccinated against measles: A cross-sectional study in two Nigerian States. *Arch Public Heal*. 2014;72:1–10. doi:
45 Tefera YA, Wagner AL, Mekonen EB, *et al*. Predictors and Barriers to Full Vaccination among Children in Ethiopia. *Vaccines (Basel)* 2018;6:22.
46 Malande OO, Munube D, Afaayo RN, *et al*. Barriers to effective uptake and provision of immunization in a rural district in Uganda. *PLoS ONE* 2019;14:e0212270.
47 Sarker AR, Akram R, Ali N, *et al*. Coverage and factors associated with full immunisation among children aged 12-59 months in Bangladesh: insights from the nationwide cross-sectional demographic and health survey. *BMJ Open* 2019;9:e028020.
48 Song IH, Palley E, Atteraya MS. Inequalities in complete childhood immunization in Nepal: results from a population-based cross-sectional study. *BMJ Open* 2020;10:1–10.
49 Asmare G, Madalicho M, Sorsa A. Disparities in full immunization coverage among urban and rural children aged 12-23 months in southwest Ethiopia: A comparative cross-sectional study. *Hum Vaccin Immunother* 2022;18:2101316.
50 Adamu AA, Uthman OA, Sambala EZ, *et al*. Rural-urban disparities in missed opportunities for vaccination in sub-Saharan Africa: a multi-country decomposition analyses. *Hum Vaccin Immunother* 2019;15:1191.
51 Hardhantyo M, Chuang YC. Urban-rural differences in factors associated with incomplete basic immunization among children in Indonesia: A nationwide multilevel study. *Pediatr Neonatol* 2021;62:80–9.
52 Santos TM, Cata-Preta BO, Wendt A, *et al*. Exploring the "Urban Advantage" in Access to Immunization Services: A Comparison of Zero-Dose Prevalence Between Rural, and Poor and Non-poor Urban Households Across 97 Low- and Middle-Income Countries. *J Urban Heal* 2024;101:638–47.
53 Eze P, Agu UJ, Aniebo CL, *et al*. Factors associated with incomplete immunisation in children aged 12-23 months at subnational level, Nigeria: a cross-sectional study. *BMJ Open* 2021;11:e047445.
54 Ataguba JE, Ojo KO, Ichoku HE. Explaining socio-economic inequalities in immunization coverage in Nigeria. *Health Policy Plan* 2016;31:1212–24.
55 Acharya K, Dharel D, Subedi RK, *et al*. Inequalities in full vaccination coverage based on maternal education and wealth quintiles among children aged 12-23 months: further analysis of national cross-sectional surveys of six South Asian countries. *BMJ Open* 2022;12:e046971.
56 Srivastava S, Muhammad T, Rashmi R, *et al*. Socioeconomic inequalities in non- coverage of full vaccination among children in Bangladesh: a comparative study of Demographic and Health Surveys, 2007 and 2017-18. *BMC Public Health* 2022;22:183.
57 Bergen N, Cata-Preta BO, Schlotheuber A, *et al*. Economic-Related Inequalities in Zero-Dose Children: A Study of Non-Receipt of Diphtheria-Tetanus-Pertussis Immunization Using Household Health Survey Data from 89 Low- and Middle-Income Countries. *Vaccines (Basel)* 2022;10:633.
58 Dadari I, Higgins-Steele A, Sharkey A, *et al*. Pro-equity immunization and health systems strengthening strategies in select Gavi-supported countries. *Vaccine (Auckl)* 2021;39:2434–44.
59 Mantel C, Cherian T. New immunization strategies: adapting to global challenges. *Bundesgesundheitsbl* 2020;63:25–31.
60 Oyo-Ita A, Oduwole O, Arikpo D, *et al*. Interventions for improving coverage of childhood immunisation in low- and middle-income countries. *Cochrane Database Syst Rev* 2023;12:CD008145.
61 Okello G, Izudi J, Ampeire I, *et al*. Two decades of regional trends in vaccination completion and coverage among children aged 12–23 months: an analysis of the Uganda Demographic Health Survey data from 1995 to 2016. *BMC Health Serv Res* 2022;22:1–17.

BMJ Open: first published as 10.1136/bmjopen-2024-093619 on 15 January 2025. Downloaded from http://bmjopen.bmj.com/ on January 21, 2025 by guest. Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.