

Immunization coverage estimates among children aged 12–23 months: Experience from a Mathare sub-county, Kenya

Michael Sileshi Mekbib¹, Joan Muchiri², Eunice Thuo², Judy Gichuki², Sharon Limo², Doris Ogolla², Damaris Inoti², Domitilla Kimani²

¹Africa Field Epidemiology Network, Nairobi, Kenya, ²Nairobi City County Health Service, Nairobi, Kenya

✉ Michael Sileshi Mekbib, Africa Field Epidemiology Network, Nairobi, Kenya
| Email: mikiethio@gmail.com | ORCID: 0009-0002-2888-690X

Article history:

Received: 03 Nov 2025

Accepted: 26 Mar 2026

Published: 09 Apr 2026

Abstract

Introduction: Immunization is a cost-effective public health intervention critical to reducing childhood morbidity and mortality from vaccine-preventable diseases. Despite national progress in Kenya, Mathare sub-county has reported persistently low routine immunization coverage, contrasting with broader Nairobi County trends. This study determined the actual immunization coverage among children aged 12–23 months in Mathare sub-county, Nairobi, and identified barriers to full immunisation.

Methods: A community-based cross-sectional survey was conducted in February 2020 using the WHO-recommended 30×7 cluster sampling technique. A total of 210 children aged 12–23 months were randomly selected across 30 clusters. Immunization status data were collected through vaccination card review and caregiver recall. Data were analyzed descriptively using SPSS version 26.

Results: Vaccination cards were available for 90.4% of children. Full immunisation coverage was 89% (95%CI: 84–93) based on combined card and recall data, compared to 77% (95% CI:71–83) by card data alone. Coverage for key vaccines (BCG, pentavalent, measles) exceeded 95% by recall but was lower when considering cards only. Approximately half of all vaccinations were administered outside Mathare sub-county (45% – 64%). Among partially immunised children (11%), the main reasons for missed doses included place and/or time of immunisation (80%), distance to immunization sites (40%), and lack of awareness of immunisation schedules (30%).

Conclusions: Immunization coverage in Mathare sub-county is substantially higher than administrative reports indicated, primarily due to significant cross-sub-county utilization of immunization services. Current sub-county reporting underestimates true coverage. Strengthening documentation, integrating private facilities into reporting systems, expanding service access, and addressing caregiver barriers through targeted outreach are essential to improving immunization equity and data accuracy.

Keywords: Immunisation Coverage, urban slum setting, coverage survey, 30×7 cluster, vaccination card, Parent's recall, partial vaccination

Citation

Suggested citation: Mekbib MS, Muchiri J, Thuo E, Gichuki J, Limo S, Ogolla D, Inoti D, Kimani D. Immunization coverage estimates among children aged 12–23 months: Experience from a Mathare sub-county, Kenya. *J. Interv. Epidemiol. Public Health* [Internet]. 2026 Apr 9;9(2):56. doi: [10.37432/jieph-d-25-00269](https://doi.org/10.37432/jieph-d-25-00269)

Copyright statement

© Michael Sileshi Mekbib et al. Journal of Interventional Epidemiology and Public Health (ISSN: 2664-2824). This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Introduction

Immunization remains one of the most cost-effective and impactful public health interventions globally, significantly reducing childhood morbidity and mortality caused by vaccine-preventable diseases (VPDs) such as measles, diphtheria, tetanus, polio, and tuberculosis. The World Health Organization (WHO) launched the Expanded Programme on Immunization (EPI) in 1974 to provide universal access to essential vaccines for children, particularly in low- and middle-income countries (LMICs) where health disparities are more pronounced [1,2]. Since its inception, the EPI has played a pivotal role in improving child survival rates, with recent estimates indicating that the EPI have averted approximately 154 million deaths globally between 1974 and 2024, with current immunization programs preventing about 6 million deaths annually [3].

In Kenya, the EPI was launched in 1980 to provide universal protection against six major childhood diseases—tuberculosis, polio, diphtheria, pertussis, tetanus, and measles—before a child's first birthday, and to offer tetanus toxoid vaccination to pregnant women to prevent maternal and neonatal tetanus [4]. Kenya's national immunization program routinely provides Bacillus Calmette-Guérin (BCG), Oral Polio Vaccine (OPV), Inactivated Polio Vaccine (IPV), Pentavalent (Diphtheria, Pertussis, Tetanus, Hepatitis B, Haemophilus influenzae), Pneumococcal Conjugate Vaccine (PCV10), Rotavirus, and Measles-Rubella vaccines through public, private, and faith-based health facilities. Kenya's Expanded Programme on Immunization (KEPI) provides seven vaccination contacts from birth to 18 months, beginning with BCG and OPV0 at birth; followed by Pentavalent, OPV, PCV, and Rotavirus vaccines at 6, 10, and 14 weeks; and Measles-Rubella at 9 and 18 months. Yellow Fever is administered in designated high-risk regions, and Vitamin A is given at 9 and 18 months. Children presenting late are offered catch-up doses to ensure full protection according to the national guidelines. [4].

Kenya is divided into 47 counties [5,6] and aims to achieve vaccination coverage of $\geq 90\%$ nationally and $\geq 80\%$ in every district. A 2021 analysis highlighted that Kenya's continuous efforts to improve vaccination coverage have resulted in increased DPT3 (or DPT-containing vaccine) coverage over the years. However, significant inequities persist, especially among the urban poor and residents of informal settlements.[7]. The WHO and UNICEF estimated that in 2019 Kenya's DTP-3 coverage among children under 12 months, is a key indicator of immunization program performance, was 93% [8]. Similarly, the Kenya Demographic and Health Survey (KDHS) conducted in 2014 showed that 74.4% of Nairobi children were fully vaccinated, 88% of surviving infants had received the third dose of a DPT-containing vaccine, and 81.2% had received a measles-containing vaccine [9].

In contrast, routine immunization reports from Mathare Sub-County indicated consistently low immunization coverage over several years (2016–2019), with 2019 figures showing only 48.6% for pentavalent first dose, 48.7% for pentavalent third dose, 51% for measles first dose, and 51.3% for fully immunized children (Table 1) [10].

These discrepancies created uncertainty around the true immunization status of children in the sub-county, potentially leading to under- or overestimation of coverage, misinformed resource allocation, and ineffective immunization strategies. Given this, the study assessed the actual immunization coverage among children aged 12–23 months in Mathare sub-county of Nairobi and identified the reasons for partial or non-immunisation through a community-based approach.

Methods

Study design and setting

This was a community-based cross-sectional survey conducted from February 1–6, 2020, using the WHO-recommended 30×7 cluster sampling method. This method is recommended by WHO as a rapid, simplified and economic approach for assessment of vaccination coverage [11].

The study was conducted in Mathare Sub-County, one of 17 sub-counties in Nairobi County, Kenya. Nairobi County is the most populous county in Kenya with an estimated population of 4.9 million, while the country's total population is estimated at 53.3 million in 2025. Mathare is an informal settlement divided into five administrative wards and 67 villages. The sub-county's population was estimated at 212,000 in 2020, with 5,576 children under one year of age. At the time of the study, there were 12 public, faith-based and private health facilities providing immunization services in the sub-county [5,6].

Study population and sample size

All 67 villages in Mathare sub-county constituted the sampling frame for cluster selection (annex I). The study population comprised children aged 12–23 months residing in Mathare sub-county. This age range was chosen because children in this group are expected to have completed their routine immunisation schedule, in line with WHO's expanded program on immunization (EPI) guidelines. In accordance with the WHO 30×7 cluster sampling methodology, a total sample size of 210 children was targeted, derived from the selection of 30 clusters with seven children per cluster.

Cluster selection

Thirty clusters (villages) were selected from the 67 villages using probability proportional to size (PPS) sampling based on village population estimates, ensuring that

villages with larger populations had a higher probability of selection. The use of 30 clusters is methodologically justified by WHO guidance, which demonstrates that this number provides stable variance estimates while limiting intracluster correlation.

Household selection

Within each selected village, field teams conducted a household listing, supported by community health volunteers (CHVs) who were familiar with the local area and household composition. The CHVs assisted in identifying and updating the list of households and in determining which households had eligible children aged 12–23 months, thereby ensuring completeness and accuracy of the sampling frame at the cluster level. From the finalised household list, households were selected using systematic random sampling until seven eligible children were enrolled per cluster. If a selected household contained more than one eligible child, only one child (the youngest) was included to avoid within-household clustering. If a selected household had no eligible child or the caregiver was unavailable, the team proceeded to the next household on the systematic list until the required number of seven eligible children was reached for that cluster.

Data collection and analysis

Training was provided to 20 data collectors (nurses) on the study's rationale, objectives, and data collection procedures. Continuous supervision and follow-up were conducted throughout data collection in all clusters to ensure quality and consistency. Vaccination status was verified primarily through written records such as the mother and child health booklet and other health cards. In cases where written documentation was unavailable, parents' recall was solicited using specific, structured questions (Annex I) about each vaccine dose. Interviewers employed probing techniques and visual aids to assist parents in accurately recalling their child's vaccination history.

Mothers or caregivers of partially immunized children were asked a multiple-response question regarding reasons for missed vaccinations. Data were analyzed using SPSS version 26. Descriptive statistics, including frequencies and proportions, were computed to summarize the findings. Ninety-five per cent confidence intervals for vaccination coverage estimates were calculated using binomial proportion methods. Results are presented in tables for clarity.

Operational definitions

Fully immunised child: A child between 12 and 23 months who received one dose of Bacille Calmette Guerin (BCG), OPV at birth, at least three doses of pentavalent vaccine, three doses of oral polio vaccine (OPV), three doses of pneumococcal conjugate vaccine (PCV), two

doses of Rotavirus vaccine and one dose of Measles Rubella vaccine by card plus parents' recall [4]

Partially immunised child: A child who missed any one or more of the above doses, and no immunization means a child who has not received even a single dose of vaccine.

Coverage by card only: Vaccination coverage calculated using only doses documented on a vaccination card, excluding children whose vaccination status was reported solely by parental history/recall.

Coverage by card plus history/parents' recall: Vaccination coverage calculated using both documented doses on the vaccination card and doses reported by the mother/caregiver based on recall.

Ethical consideration

Permission to conduct the immunisation coverage survey was obtained from the Mathare/Starehe sub-county Health Management. Written informed consent was obtained from all parents or legal guardians before data collection. Participation in the study was entirely voluntary, and respondents were informed of their right to decline or withdraw at any point without consequence. The survey did not involve any intervention, experimentation, or administration of vaccines. No personally identifiable information was collected, and data were handled with strict confidentiality. The immunisation coverage survey was determined to be exempt from Institutional Review Board (IRB) review because it constituted routine public health program monitoring, involved no interventions, and did not collect identifiable personal information, consistent with national ethical guidelines.

Results

A total of 210 parents of children aged 12–23 months were interviewed with a response rate of 100 %. The children's mean age was 17 months (SD=2.7). The majority, 192 (92.4%), were born at health facilities.

Among the 210 children included in the study, immunisation cards were available for 190 children (90.4%). For the remaining children, vaccination status was determined through parental recall. Combining data from immunisation cards and parental recall, 89% (95% CI: 84–93) of the children were fully immunised, while the remaining 11% were partially immunised. No completely unvaccinated children were identified. A comparatively lower percentage of children received the OPV dose at birth, 93% (95% CI: 89–96), compared to 98% (95% CI: 96–100) who received BCG. No significant drop in vaccination coverage was observed between the first, second, and third doses of the pentavalent vaccine (Table 2).

Table 1. Immunization coverage from administrative reporting, 2016–2019

Immunization Coverage	Kenya				Mathare Sub County				Nairobi County			
	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019
Proportion of children under one year who are fully immunized	73.6	66.5	77.5	77.3	54.6	57.1	54.9	51.4	84.2	85.1	87.2	87.5
Proportion of under 1 year receiving Rota 1	80.6	73.2	84.2	83.7	57.5	55.4	55.7	49.0	96.2	90.1	91.6	89.8
Proportion of under 1 year receiving DPT/Hep+HiB1	84.1	76.1	85.2	84.4	60.2	56.1	56.1	48.6	97.9	90.0	91.6	89.9
Proportion of under 1 year receiving DPT/Hep+HiB3	78.6	68.4	81.8	80.3	59.1	54.3	56.7	48.7	93.1	84.1	86.8	85.4
Proportion of under 1 year receiving OPV 2	78.6	69.8	80.9	77.3	59.8	55.3	55.6	47.6	93.4	86.8	88.4	85.7
Proportion of under 1 year receiving OPV birth dose	68.7	61.3	72.9	69.7	32.8	45.4	31.0	26.5	102.4	96.0	94.7	90.9
Proportion of under 1 year receiving vaccine against Measles and Rubella 1	75.0	68.6	79.4	78.5	54.8	56.1	54.0	51.0	87.9	88.1	89.0	88.6
Proportion of under 1 year receiving OPV 1	82.9	74.7	84.4	80.7	60.3	57.2	55.7	49.2	97.4	89.0	92.0	87.9
Proportion of under 1 year receiving OPV 3	76.5	66.5	80.6	76.1	58.6	53.7	56.5	48.6	91.3	82.9	86.0	83.6
Proportion of under 1 year receiving BCG	86.0	80.0	86.0	84.0	43	50	33	27	100	101	96	94

When considering only the information from immunization cards, 77% (95% CI: 71–83) of children were fully immunized. BCG and pentavalent vaccines were the most administered, with coverage rates of 88% (95% CI: 83–92) and 87% (95% CI: 83–92), respectively. In contrast, OPV at birth and the first dose of measles vaccine were the least administered, each with a coverage of 83% (95% CI: 78–88). The dropout rate from the first dose of the pentavalent vaccine to the first dose of the measles vaccine was estimated at 4%.

Place where children received immunization

The boundaries between sub-counties in Nairobi County serve administrative purposes only. Parents are free to take their children to the nearest health facility for immunization, regardless of the sub-county in which the facility is located. Therefore, it was important to determine the locations where children received each vaccine. According to immunisation cards and parental recall, approximately half of the children received vaccinations for schedules starting at six weeks or older at facilities within Mathare Sub-County. The other half (45% – 64%) were vaccinated at facilities situated in neighbouring sub-counties or counties (Table 3). Similarly, only about one-third of children received BCG (36.2%) and OPV at birth (36.7%) at facilities located in Mathare Sub-County. The survey also identified private facilities (3 facilities) offering immunisation services but not reporting data to the sub-county health authorities.

Reasons for partial immunization

Among the 210 children, 23 (11%) missed at least one recommended vaccine dose before reaching their first birthday. Of these respondents, 80% reported that the place and/or time of immunization was unknown, 40%

indicated that the immunization site was too far from home, and 30% cited mothers being too busy as reasons for missing one or more scheduled doses (Table 4).

Discussion

This study demonstrates high immunization coverage among children aged 12–23 months in Mathare sub-county, indicating substantial progress in vaccine uptake in this urban informal setting. Coverage estimates based on immunization cards alone were comparable to those reported for Nairobi County in the 2022 Kenya Demographic and Health Survey (KDHS), and higher than estimates reported in the 2014 KDHS and the 2019 Mathare sub-county administrative report [9,10,12]. These findings suggest improvements in access to and utilization of immunization services over time, despite persistent structural challenges in slum settings.

However, coverage estimates were consistently higher when parental recall was included, with differences ranging from 10% to 13% compared to card-only estimates. This pattern is consistent with evidence from a global systematic review, which documented wide discrepancies between vaccination card data and parental recall, ranging from –40 to +56 percentage points. As observed in similar studies, this discrepancy may be explained by several factors, including incomplete documentation by healthcare workers, parental recall bias, lost or damaged cards, or children receiving vaccinations at multiple facilities. This underscores the need for strengthened and consistent documentation practice by providers and targeted health education to caregivers [13–15].

Coverage for individual antigens was high and broadly consistent with national survey estimates. Coverage for the first dose of pentavalent vaccine and the first dose of the

Table 2. Percentage of children age 12–23 months who received specific vaccines according to a vaccination card and card plus parent’s recall in Mathare sub county, Nairobi Kenya

Antigen / Vaccine	Vaccination Card (n=153)		Card + Recall (n=205)	
	%	(95% CI)	%	(95% CI)
BCG	94.1	(89.7–97.1)	95.1	(91.2–97.6)
OPV0 (Birth)	57.5	(49.4–65.3)	65.9	(59.1–72.2)
OPV1	90.2	(84.3–94.4)	93.2	(88.8–96.2)
OPV2	86.9	(80.5–91.8)	90.7	(85.8–94.4)
OPV3	85.6	(78.9–90.8)	89.8	(84.7–93.6)
DPT/HepB/Hib1	90.8	(85.1–94.9)	94.1	(90.1–96.9)
DPT/HepB/Hib2	88.9	(82.7–93.4)	92.7	(88.1–95.9)
DPT/HepB/Hib3	86.3	(79.6–91.4)	90.7	(85.8–94.4)
PCV1	90.2	(84.3–94.4)	93.7	(89.4–96.5)
PCV2	88.2	(81.9–92.9)	92.2	(87.5–95.5)
PCV3	85.0	(78.1–90.3)	89.8	(84.7–93.6)
Rota1	90.8	(85.1–94.9)	93.7	(89.4–96.5)
Rota2	86.9	(80.5–91.8)	91.2	(86.4–94.7)
Measles-Rubella 1	81.7	(74.5–87.6)	86.8	(81.3–91.2)
Fully Immunized	67.3	(59.3–74.6)	76.1	(69.7–81.7)

measles-containing vaccine (MCV1) aligned with DHS findings for Nairobi County in both 2014 and 2022 [8,11]. Coverage for the third dose of pentavalent vaccine, based on immunization cards alone, was slightly lower than the WHO–UNICEF 2019 national estimate (93%) but comparable to the 2022 DHS estimate of 89.2% [8,12].

High BCG coverage in this study should be interpreted in the context of service utilization patterns. Although overall coverage was high, only about one-third of children received BCG within facilities in Mathare sub-county, with substantially lower coverage reported in local administrative data [10]. This likely reflects reliance on maternity hospitals in neighboring sub-counties for deliveries. Exceptionally high BCG coverage reported by the nearest maternity hospital in Kamukunji sub-county further supports this cross-boundary utilization and highlights limitations of geographically defined routine

Table 3. Place of immunization among immunized children in Mathare sub county, Nairobi Kenya

Place of Immunization	# of children (n=205)	(%)
Government health facility	142	69.3
Private health facility	28	13.7
Outreach / Mobile clinic	19	9.3
Home / Community	11	5.4
Other	5	2.4

Table 4. Reasons mentioned by parents/care givers for partial immunization in Mathare Sub county, Nairobi Kenya

Reasons for Partial Immunization	Percentage (n=23)
Place and/or time of immunization unknown	80%
Place of immunization too far	40%
Time of immunization inconvenient	5%
Mother too busy	30%
Family problem, illness of mother	15%
Child ill – brought but not given immunization	15%
Long waiting time	10%
No money to pay for immunization or transportation	15%

data in urban informal settings [10]. On the other side OPV at birth coverage was comparatively lower. This discrepancy may reflect differences in service delivery practices at birth, including vaccine availability or prioritization of BCG administration at maternity facilities.

Despite high early-dose coverage, modest attrition across the immunization schedule was observed. The low dropout from the first dose of pentavalent vaccine to the first dose of measles-containing vaccine is consistent with findings from urban slums of Nairobi, where competing caregiver demands and access barriers affect completion of later doses [16].

The marked differences between cluster survey estimates and routine administrative coverage data for Mathare sub-county further illustrate structural challenges in immunization monitoring [(9,10,12)]. Nearly half of the children in the target population reportedly received vaccinations outside the sub-county, complicating denominator-based administrative reporting. Limited numbers of immunizing facilities, irregular service schedules, and the proximity of better-resourced facilities in neighboring sub-counties likely contribute to this pattern. Previous studies in 10 diverse counties of Kenya and other low- and middle-income countries have similarly documented how irregular service availability and scheduling barriers negatively affect immunization uptake and completion. [17-19].

Although the study’s primary focus is coverage, the high vaccination card retention observed (90.4%) provides useful context for interpreting card-based estimates. It was high (90.4%), exceeding rates reported in the Kenya DHS 2014 and 2022 and studies from Ethiopia (52.5% – 64.7%) [9,12,20], but comparable to findings from urban Ghana (91.5%) [21]. This may reflect the urban setting and differences in survey timing and methodology.

Finally, although overall coverage was high, some children remained partially immunized. Barriers reported by caregivers, time constraints, distance, and limited information about service timing are consistent with evidence from urban low-income settings [18,22,23]. Addressing these barriers may require more flexible, accessible, and well-communicated immunization services, particularly in slum areas where families face compounded structural and social barriers. Tailored interventions such as mobile outreach, daily immunization schedule, and community-based health education may address these missed opportunities and improve coverage equity.

Limitations

This study has several limitations. First, reliance on parental recall to determine immunization status may introduce recall bias, potentially affecting the accuracy of the findings. Second, the cross-sectional nature of the study limits the ability to draw causal inferences between variables. Additionally, the absence of socioeconomic data restricts deeper analysis of factors influencing immunization coverage. Finally, variations or inaccuracies in sub-county boundary definitions may limit the generalizability of the results to other settings.

Conclusions

This community-based immunization coverage survey conducted in Mathare sub-county reveals a substantially higher proportion of fully immunized children (89%) than previously reported in the 2019 routine administrative data (51.3%). The findings suggest that official administrative

records may significantly underestimate true immunization coverage in underserved urban settings, primarily due to cross-sub-county utilization of vaccination services. Nearly half of the children included in Mathare’s target population were immunized in facilities outside the sub-county, a factor not captured in Mathare’s administrative reports. This highlights a critical limitation in the current sub-county-based reporting system, particularly in urban contexts where geographic and administrative boundaries do not align with care-seeking behavior.

Despite the high coverage observed, discrepancies between vaccination card-only data and combined card-plus-recall data, point to persistent gaps in documentation and the need for improved recording practices. The 11% partial immunization rate warrants attention to ensure that children complete the full immunization schedule. Additionally, logistical barriers such as distance to health facilities, lack of awareness of immunization schedules, and caregiver availability were identified as key reasons for missed vaccinations.

The study highlights the need to strengthen both immunization service delivery and data management systems in Mathare sub-county. Key priorities include improving documentation practices and expanding equitable access to immunization services. Special attention should be given to integrating private health facilities into the routine reporting system and addressing caregiver-related barriers through targeted health education and community outreach. Tailored delivery strategies such as child-friendly services, flexible clinic hours, and mobile outreach combined with enhanced use of digital data collection tools, can improve both coverage and continuity of care. Further research is recommended to explore the underlying determinants of immunization service utilization in neighboring sub-counties, which may inform more localized and effective interventions.

What is already known about this topic

- Despite overall improvements in immunization coverage at the national and county levels in Nairobi, Kenya, administrative data from Mathare sub-county have consistently indicated low immunization coverage over several years, particularly in underserved informal settlements

What This Study Adds

- This study provides community-based, validated estimates of immunization coverage among children aged 12–23 months in Mathare sub-county, highlighting discrepancies with administrative data.
- It also offers insights into the specific locations where children received vaccinations, supporting targeted planning and service delivery improvements.

Conflict of Interest

The authors of this work declare no competing interests.

Funding

Afya Jijini covered the cost for the data collectors. The funder had no role in the design of the manuscript, data analysis, interpretation, or the decision to publish.

Acknowledgments

We acknowledge all study participants for their time and understanding during the data collection period. We also acknowledge the Starehe/Mathare sub-county Health Management Team for granting us permission to conduct the study. We also extend much gratitude to Afya Jijini for covering the costs of printing questionnaires and data collectors' allowance.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

Joan Muchiri, Eunice Thuo, Judy Gichuki, Sharon Limo, Doris Ogolla, Damaris Inoti, and Domitilla Kimani each contributed as RO with roles including Conceptualization, Data curation, Project administration, Resources, Supervision, and Writing – review editing (with some also contributing Investigation). Michael Sileshi Mekbib contributed Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, and Writing – review editing.

References

- [1] World Health Assembly (27th: 1974). The Expanded Programme on Immunization: the 1974 Resolution by the World Health Assembly. *Assign Child*. 1985 [cited 2026 Apr 9];69-72:87-8. Available from:<https://pubmed.ncbi.nlm.nih.gov/12280461/> Abstract only
- [2] Greenwood B. The contribution of vaccination to global health: past, present and future. *Philos Trans R Soc Lond B Biol Sci* [Internet]. 2014 Jun 19 [cited 2026 Apr 9];369(1645):20130433. Available from: doi:10.1098/rstb.2013.0433
- [3] Shattock AJ, Johnson HC, Sim SY, Carter A, Lambach P, Hutubessy RCW, Thompson KM, Badizadegan K, Lambert B, Ferrari MJ, Jit M, Fu H, Silal SP, Hounsell RA, White RG, Mosser JF, Gaythorpe KA, Trotter CL, Lindstrand A, O'Brien KL, Bar-Zeev N. Contribution of vaccination to improved survival and health: modelling 50 years of the Expanded Programme on Immunization. *Lancet* [Internet]. 2024 May 2 [cited 2026 Apr 9];403(10441):2307-2316.doi:10.1016/S0140-6736(24)00850-X
- [4] Ministry of Health, Kenya. Kenya National Immunization Policy Guidelines 2023 [Internet]. Nairobi (Kenya): Ministry of Health, Kenya; 2023 Apr [cited 2026 Apr 9]. 84 p. Available from:<https://www.dknowledge.co.ke/sas/s/notes/Kenya-National-Immunization-Policy-Guidelines-Version-signed.pdf>
- [5] Kenya National Bureau of Statistics. 2019 Kenya Population and Housing Census: Volume 1: Population by County and Sub County [Internet]. Nairobi (Kenya): KNBS; 2019 Nov [cited 2026 Apr 9]. 38 p. Available from:<https://www.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-1-Population-By-County-And-Sub-County.pdf>
- [6] Kenya National Bureau of Statistics. 2019 Kenya Population and Housing Census: Volume 3: Distribution of Population by Age and Sex [Internet]. Nairobi (Kenya): KNBS; 2019 Dec [cited 2026 Apr 9]. 506 p. Available from:<https://www.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-3-Distribution-of-Population-by-Age-and-Sex.pdf>
- [7] Allan S, Adetifa IMO, Abbas K. Inequities in childhood immunisation coverage associated with socioeconomic, geographic, maternal, child, and place of birth characteristics in Kenya. *BMC Infect Dis* [Internet]. 2021 Jun 11 [cited 2026 Apr 9];21(1):553. 10.1186/s12879-021-06271-9
- [8] World Health Organization, United Nations Children's Fund. WUENIC trends [Internet]. Geneva (Switzerland): WHO; [cited 2026 Apr 9]. Available from:<https://worldhealthorg.shinyapps.io/wuenic-trends/>
- [9] Kenya National Bureau of Statistics, Ministry of Health/Kenya, National AIDS Control Council/Kenya, Kenya Medical Research Institute, National Council for Population and Development/Kenya, ICF International. Kenya Demographic and Health Survey 2014 [Internet]. Nairobi (KE): KNBS; 2015 Dec [cited 2026 Apr 9]. 575 p. Available from:<https://dhsprogram.com/pubs/pdf/fr308/fr308.pdf>
- [10] Kenya District Health Information System 2 (DHIS2) [Internet]. Nairobi (Kenya): MOH (Kenya). 2020 Jan – [cited 2026 Apr 9]. Available from:<https://hiskenya.org/dhis-web-commons/security/login.action> Credentials required to access database
- [11] World Health Organization. World Health Organization Vaccination Coverage Cluster Surveys: Reference Manual [Internet]. Geneva(Switzerland): World Health Organization; 2018 Jun 12 [cited 2026 Apr 9]. 217 p. Available from:<https://www.who.int/publications/i/item/WHO-IVB-18.09> WHOReferenceNumber:WHO/IVB/18.09
- [12] Kenya National Bureau of Statistics, Ministry of Health/Kenya, National AIDS Control Council/Kenya, Kenya Medical Research Institute, National Council for Population and Development/Kenya, ICF International. Kenya Demographic and Health Survey 2022: Volume

- 1 [Internet]. Nairobi (KE): KNBS; 2023 June [cited 2026 Apr 9]. 656 p. Available from: <https://dhsprogram.com/pubs/pdf/FR380/FR380.pdf>
- [13] Luman ET, Ryman TK, Sablan M. Estimating vaccination coverage: validity of household-retained vaccination cards and parental recall. *Vaccine* [Internet]. 2008 Oct 21 [cited 2026 Apr 9];27(19):2534-9. doi:10.1016/j.vaccine.2008.10.002
- [14] Miles M, Ryman TK, Dietz V, Zell E, Luman ET. Validity of vaccination cards and parental recall to estimate vaccination coverage: A systematic review of the literature. *Vaccine* [Internet]. 2012 Nov 26 [cited 2026 Apr 9];31(12):1560-8. doi:10.1016/j.vaccine.2012.10.089
- [15] Binyaruka P, Borghi J. Validity of parental recalls to estimate vaccination coverage: evidence from Tanzania. *BMC Health Serv Res* [Internet]. 2018 Jun 13 [cited 2026 Apr 9];18(1):440. doi:10.1186/s12913-018-3270-z
- [16] Mutua MK, Kimani-Murage E, Ettarh RR. Childhood vaccination in informal urban settlements in Nairobi, Kenya: Who gets vaccinated? *BMC Public Health* [Internet]. 2011 Jan 4 [cited 2026 Apr 9];11(1):6. doi:10.1186/1471-2458-11-6
- [17] Li AJ, Tabu C, Shendale S, Sergon K, Okoth PO, Mugoya IK, Machekanyanga Z, Onuekwusi IU, Sanderson C, Ogbuanu IU. Assessment of missed opportunities for vaccination in Kenyan health facilities, 2016. *PLoS One* [Internet]. 2020 Aug 20 [cited 2026 Apr 9];15(8):e0237913. doi:10.1371/journal.pone.0237913
- [18] Zimba B, Mpinganjira S, Msosa T, Bickton FM. The urban-poor vaccination: Challenges and strategies in low-and-middle income countries. *Hum Vaccin Immunother* [Internet]. 2024 Jan 02 [cited 2026 Apr 9];20(1):2295977. Available from: <https://www.tandfonline.com/doi/full/doi:10.1080/21645515.2023.2295977>
- [19] Babirye JN, Rutebemberwa E, Kiguli J, Wamani H, Nuwaha F, Engebretsen IMS. More support for mothers: a qualitative study on factors affecting immunisation behaviour in Kampala, Uganda. *BMC Public Health* [Internet]. 2011 Sep 25 [cited 2026 Apr 9];11(1):723. doi:10.1186/1471-2458-11-723
- [20] Tareke AA, Tewabe Ayelign A, Yewodiaw TK, Shiferaw EW, Eshetu HB, Enyew EB. Retention rate of vaccination card and its associated factors among vaccinated children aged 12-23 months in Ethiopia: Multilevel logistic regression analysis. *PLoS One* [Internet]. 2024 Jul 11 [cited 2026 Apr 9];19(7):e0306421. doi:10.1371/journal.pone.0306421
- [21] Konlan MY, Mahama F, Abubakari BB, Konka P, Appiah BO, Yeboah MO, Kwarteng PG, Apea PO, Adjei MR, Adokiya MN, Boadum O, Abiwu HAK. Predictors of vaccination card retention in Tamale Metropolis, Ghana. *PLoS One* [Internet]. 2024 Feb 26 [cited 2026 Apr 9];19(2):e0292765. doi:10.1371/journal.pone.0292765
- [22] Mebrat A, Dube L, Kebede A, Aweke Z. Determinants of Incomplete Childhood Vaccination among Children Aged 12-23 Months in Gambela Region, Southwest Ethiopia: A Case Control Study. *Ethiop J Health Sci* [Internet]. 2021 Jan 1 [cited 2026 Apr 9];31(1):63-72. doi:10.4314/ejhs.v31i1.8
- [23] Kefeni BT, Chibsa SE, Roba Debele G. Determinants of incomplete penta vaccination among children aged 12 to 23 months in South-West Ethiopia. *Sci Rep* [Internet]. 2024 May 31 [cited 2026 Apr 9];14(1):12561. doi:10.1038/s41598-024-62153-5