Review Article

Emerging Methodologies Used in Assessing Childhood Vaccination Coverage: A Comparative Scoping Review

Sundeep Sahitia, Idayu Badilla Idris, Nazarudin Safian, Khadijah Shamsuddin and Rozita Hod

ABSTRACT

Objective: This review critically compares existing and emerging methods used to assess childhood vaccination coverage in developing countries to determine their strengths, weaknesses, accuracy, efficiency, inherent biases, and suitability based on their unique challenges.

Results: The methodologies reviewed included administrative data, household surveys (Demographic Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS) and Lot Quality Assurance Sampling (LQAS), school-based assessments, and serosurveys. Administrative data often suffers from inaccuracies and data manipulation tendencies. Household surveys, especially DHS and MICS, offer detailed insights but are resource-intensive and require specialized expertise. School-based assessments, while easy to implement, face generalizability constraints. Serosurveys are resource-intensive but uniquely gauge effective vaccination coverage through immunity profiling. A novel approach such as LQAS emerges as a rapid and suitable method for resource-limited settings. MICS Plus is also a recent innovative extension that effectively assesses seasonality effects.

Conclusion: This review serves as an updated guide with novel developments for policymakers, health professionals, and program implementers to make informed decisions on vaccination coverage assessment. Combining methods like LQAS with household surveys and following them with the MICS Plus model can yield optimal results for developing countries.

Key Words: Vaccination; Surveys; Methodologies

Citation of article: Sahitia S, Idris IB, Safian N, Shamsuddin K, Hod R. Emerging Methodologies Used in Assessing Childhood Vaccination Coverage: A Comparative Scoping Review. Med Forum 2023;34(12):84-89. doi:10.60110/medforum.341220.

INTRODUCTION

Vaccination stands as a monumental achievement in the history of medicine, safeguarding millions of children from infectious diseases annually since the innovative work of Edward Jenner in late 18th century[1,2]. Its benefits extend beyond just individual protection and encompass social and economic developments[3-5]. Generally, the global childhood vaccination average masks significant disparities at the micro-level. High-income countries often report coverage rates exceeding 90%, while nations in regions like sub-Saharan Africa and Asia struggle with barriers ranging from infrastructural deficits to civil unrest position populations at risk from diseases such as measles[6-8].

Therefore, cost-effective, reliable, accurate and periodic assessment of childhood vaccination coverage becomes imperative, particularly in developing countries, where the trends exhibit pronounced fluctuations. To this end, several methodologies have been developed i.e., administrative data, household-based surveys, school-based screenings, and others[9]. Yet, as methodologies proliferate, so do challenges in their application; i.e., lack of accuracy and reliability, overestimations, and underestimations. Overall, these challenges have created an ambiguity around methodologies.

This review addresses this gap and compares the various methodologies available for evaluating vaccination coverage, weighing their strengths and weaknesses, and considering their suitability in different contexts. We aim to provide policymakers and stakeholders, especially those in developing countries, with insights to aid in selecting suitable assessment methods based on the available resources and aims, thereby ensuring that all children gain the benefits of immunization.

Department of Public Health Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia.

Correspondence: Sundeep Sahitia, PhD Scholar, Department of Public Health Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia Jln Yaacob Latif, Bandar Tun Razak, Cheras, Kuala Lumpur 56 000, Malaysia.
Contact No: (+92) 3337274212
Email: sundeep_sahitia@hotmail.com

Received: July, 2023
Accepted: September, 2023
Printed: December, 2023

RESULTS

Administrative Data: Administrative data reports are widely cost-effective implemented methods of data presentation about the records of vaccine doses, both received and administered[9,13]. These data are predominantly managed using electronic health information systems or, in some instances, manually through booklets and registers[10-12]. They undergo collection, compilation, and conversion into a structured format across various tiers, from private health facilities to broader provincial levels, to ascertain an overall vaccination coverage estimate[10]. However, it comes at the cost of coverage bias due to the misrepresentation of selective populations[14]. The introduction of digital data recording systems augments its efficiency, enabling near real-time monitoring, which is indispensable for quick decision-making[12].

Household Surveys

Demographic Health Surveys (DHSs): DHS is a cornerstone variant of household survey established in the 1980s, which offers extensive data on population, health and nutrition through nationally representative data[15,16]. These surveys are carried out primarily for impact evaluation of health interventions. Customizable questionnaires are used to capture a wide range of indicators, from fertility to health themes. Due to its robust methodology, DHS is structured to ensure comparability across countries and over time, making it a valuable resource for trend analyses[15-17].

Table No.1: Strengths, weaknesses and minimum required sample size of each methodology

No.	Methodology	Sample size (minimum required)	Strengths	Weaknesses
1	**Administrative data** (Routine reports/electronic registry databases)	At least 50,000 population per district	a) Cost-effective b) Large sample size c) Easy to monitor and track coverage, missed opportunities, and dropout rates d) Reminders e) Real-time data	a) Inaccurate denominators b) Excluded private sector c) Data manipulation d) Transcription errors **Electronic registry:** f) Highly trained human resource g) Duplicate records h) Difficult to track migrants
2	**Demographic Health Surveys** (DHS)	15,000 households (Rural: 30–40 women Urban: 20–25 women per cluster)	a) Includes vaccinations from outside formal system b) Other indicators are also assessed c) Two-stage sampling with high response rates >90% d) Quality trainings (4 weeks) e) National coverage estimates f) Comparable dataset through STATcompiler	a) Exclusion of populations i.e., nomads b) Measurement error due to the conflation of answers
3	**Multiple Indicator Cluster Surveys** (MICS)	10,000 households (15–30 HHs per cluster)	a) High-quality and comparable microdata b) Other indicators taken into consideration c) Both men and women are interviewed d) High response rate e) Two-stage sampling f) Changes in residency factor g) High-quality training (3 weeks) h) MICS Plus is a strong sub-variant	a) MICS data may require 2 years for presentation; on average, 12–13 months for the first draft of the report
4	**Lot Quality Assurance Sampling** (LQAS)	95 at the district level (19 /SA)	a) Require small sample size b) Works identically to stratified sampling c) Highly cost- and time-effective d) Rapid testing methodology e) Does not require advanced statistical trainings f) Classifies results into well-performing and poorly performing units	a) Confidence intervals for individual districts are not especially informative b) Requires additional statistical methods to convert the results to be generalizable
5	**School**-based assessments	Not specific	a) Can capture a large proportion of children who are usually missed in households b) Easy access c) Identify areas of missed or poor coverage d) High enrolment allows for effective assessment	a) May miss children not enrolled in school/home-schooled/unenrolled b) Limited information as age-appropriate vaccination data may be missed c) Only children within specific age groups can be assessed d) Robust school infrastructure is required
6	**Serological surveys**	177–1000	a) Direct measure of immunity b) Assess effective coverage	a) Costly and logistically challenging b) Vaccination could be from natural infection c) Underestimation due to waning immunity d) Non-participation and ethical issues e) Poor sensitivity scores f) Require highly skilled human resources

Table No.2: Biases, Accuracy and Classification strengths

		Characteristics				Precision and classification strength		
No.	**Methodology**	**Bias**	**Accuracy and validity**	**Feasibility**	**Represen-tativeness**	**National**	**Provincial**	**District**
1	**Administrative** Data	Coverage bias	Weak	Easy	Yes	Yes	No	No
2	**DHS**	a) Selection bias b) Sampling bias c) Recall bias	Strong	Difficult	Yes	Yes	Yes	Yes
3	**MICS**		Strong	Difficult	Yes	Yes	Yes	Yes
4	**LQAS**	Interpretation bias	Weak	Easy	Yes	No	Conditionall y	Yes
5	**School-based** Assessments	Cognitive bias	Weak	Easy	No	No	No	Yes
6	**Serological Surveys**	Information bias	Strong	Difficult	Yes	No	Yes	Yes

Table No.3: Waning immunity profile

Vaccine type	Duration
BCG[*1] (single dose)	10–60 years
Hepatitis B0 (single dose)	11–15 years
OPV (after 0, 1, 2, 3 doses)	> 5–10 years (within ≥ 80% of the vaccinated cohort)
Pentavalent (after 1, 2, 3 doses)	18 months (based on only 1 study)
PCV[*2] (after 1, 2, 3 doses)	3–5 years
Rota (after 2 doses)	Several years (exact details are not known)
IPV (after 2 doses)	≥ 18 years
MMR[*3] (after 2 doses)	Lifelong protection against measles and rubella; protection against mumps starts to decline in later life
TCV[*4] (single dose)	2–7 years (under study)
Td[*5] (after 5 doses)	None at 1st dose, 3 years at 2nd dose, 5 years at 3rd dose, 10 years at 4th dose, lifetime at 5th dose
Influenza vaccine	90 days

[*1] BCG: Bacille Calmette-Guerin
[*2] PCV: Pneumococcal conjugate vaccine
[*3] MR: Measles-Rubella
[*4] TCV: Typhoid conjugate vaccine
[*5] Td: Tetanus diphtheria

The core of the DHS methodology involves conducting face-to-face interviews with women (typically aged 15–49 years) and, in some surveys, men (often aged 15–59 years) in sampled households. The sampling process employs a two-stage stratified sampling design: the first stage involves selecting clusters (usually enumeration areas) from a master sampling frame, and the second stage involves the systematic sampling of households within these clusters[16,17]. Additionally, DHS often incorporates biomarker data, such as anthropometric measurements, Human Immunodeficiency Virus (HIV) testing and anaemia testing, providing a more holistic health profile. The strengths and weaknesses of the DHS methodology are summarized in table 1. This popular methodology has been adopted in more than 90 low- to middle-income countries[17].

Multiple Indicators Cluster Surveys (MICS): Another popular survey method is MICS, which provides high-quality comparable microdata on a wide range of areas such as nutrition, fertility, mortality, contraceptive use, unmet need, maternal and newborn health, female genital mutilation, menstrual hygiene management, child illness and treatment, and child development[18]. Men aged 15–49 years are interviewed individually, while women are data sources for themselves and children under the age of 18 residing within the same house[18]. This type of survey is conducted to monitor the trends of progress on the SDGs and has been implemented in around 116 countries[18].

MICS Plus: MICS Plus is an innovative sub-variant of MICS that capitalizes on the use of mobile phones for data collection on specific indicators from a subset of households surveyed in the primary MICS[19]. In this sub-variant, data collection via telephonic interviews continues for 12 months, with intervals of 1–2 months. Information is gathered from one well-informed adult in each sampled household. The primary emphasis of MICS Plus is on indicators like education, nutrition, health and child protection that might be influenced by seasonality[19].

Lot Quality Assurance Sampling: Originally developed in 1920s for the industrial quality checks, Lot Quality Assurance Sampling (LQAS), is a distinct approach with the potential to accommodate random and clustered sampling techniques with smaller sample sizes[20,21]. Instead, it categorizes administrative and geographical areas into priority zones based on predetermined targets for specific indicators. LQAS is preferred over many other sampling techniques due to its efficiency and reduced logistical needs[21]. Supervision Areas (SAs) are first identified and then sampled, with a minimum requirement of 19 per SA. The SAs are then assessed based on the predefined decision rule, and thresholds (upper and lower) are decided. Interestingly, the introduction of the direct

adjustment method has overcome the limitation of generalizability in LQAS but still lacks the identification of missed opportunities for simultaneous vaccinations (MOSV)[22].

School-based Assessment: Schools are also considered potential sites for the assessment of childhood vaccination coverage through school-based nurses or nominated staff[23,24]. This methodology not only helps in identifying pockets of under-vaccinated students, enabling schools and health departments to proactively address potential outbreaks, but also leverages the high enrolment rates in schools to ensure widespread vaccine delivery[25,26]. The scope of these assessments is though geographically limited as they capture data mainly from children attending schools above the recommended age of vaccinations and potentially miss out on home-schooled or unenrolled children[27].

Serosurveys: Seroprevalence studies are one of the most technical approaches in providing estimates of population-level immunity using cross-sectional designs for antibody detection[28]. These studies may involve serum collection through blood samples, clotted blood spot sampling or oral fluids[29]. Many developing countries have been using this methodology for measuring effective vaccination coverages rather than crude coverages[13,29]. Crude vaccination coverage measures the number of children vaccinated, while effective vaccination coverage refers to the level of immunity that is generated in response to vaccination. Serology can also be used to assess the impact of vaccination on disease burden and progress towards the elimination of a set vaccine-preventable disease. Besides the tendency of misclassification error, the issues of low sensitivity associated with oral fluid sampling may further underestimate coverage rates too[10,29].

Overall Comparison and Novelty of Methodologies: Our review compared the strengths, weaknesses, and some recent modifications of several popular methodologies which have been implemented over the years for the evaluation of childhood vaccination coverage. Our literature search suggested that administrative data offer a macro-level perspective[12], whereas household surveys, like DHS and MICS, provide micro-level insights by directly interacting with households[30]. Remarkably, innovative sub-variants like MICS Plus have emerged, capitalizing on mobile technology to enable continuous and adaptive data collection over extended periods, especially for indicators which are prone to change due to seasonality[19]. Our detailed search revealed that LQAS, with its unique sampling approach, is a modified approach which offers a rapid means to assess and categorize geographical areas based on vaccination targets[21]. This detailed review also highlighted that school-based assessments are limited in scope but utilize educational infrastructure for vaccination monitoring[25], while serosurveys capitalize on their ability to assess the actual immunity levels in populations following vaccination[28]. Table 1 provides an overview of the comparison. Table 2 illustrates biases and feasibility, with representation at different levels.

Comparison of Accuracy and Reliability: While administrative data offer a vast coverage scale, their accuracy and reliability can be compromised due to an easy approach to data manipulation, incomplete records, over-reporting, and under-registration of the target population[14]. On the other hand, household surveys like DHS and MICS are comprehensive but can also be influenced by biases such as parental recall, respondent desirability bias, and vaccine card availability which lower the overall accuracy of the surveys. MICS has though strived to improve its methodology especially to address the response rate for increasing accuracy. The missing of certain population groups also undermines the reliability of both survey designs[30,32]. Whereas LQAS is effective at classifying areas, it does not estimate population sizes, which may limit its use for large-scale insights[31]. Interestingly, its reproducibility also depends on the robust use of Bayesian or Hypergeometric distribution for assertive sample size calculations Operating and Risk Curves[31]. The subvariant MICS Plus might face skewed data challenges related to non-response bias and its reliability alters with the magnitude of potential recall bias. Similarly, school-based assessments are also prone to selection bias as they may not be representative of all children, especially those not attending school[27]. Finally, accuracy in serosurveys is affected due to biases from false positive/negative test results along with waning immunity (table 3)[10] and its reliability thus sticks to the area of misclassification range[29].

Comparison of Sampling Techniques and Ease of Data Collection: Traditional sampling is not typically employed in administrative data assessments, which aim to capture entire populations from healthcare facilities[10] and hence data is always readily available. However, household surveys like DHS and MICS work on sampling approaches, such as stratified multistage cluster sampling, making them universally comparable within the sample size of 10,000 – 15,000[30]. MICS differs from DHS in that its foundation rests on census data as the first sampling frame while DHS operates based on enumerating areas. MICS Plus usually relies on the subset random sampling of the primary MICS dataset. Remarkably, LQAS operates via a distinct random sampling methodology predetermined by upper and lower thresholds[33]. It also tends to introduce interpretation bias if the null hypothesis is not properly framed according to Bayesian or Hypergeometric distribution by keeping α and β errors within limits[31,33]. This interpretation bias can be addressed through the

implementation of objective decision rules[31]. In contrast, school-based assessments inherently bias their sampling towards school-attending children only and are mostly easy to conduct. Of all the approaches, serosurveys are though highly resource-draining but often utilize the simplest method of cross-sectional sampling to provide a snapshot of immunity levels within a given population at a particular time.

CONCLUSION

Assessing childhood vaccination coverage is complex as each methodology presents unique advantages and limitations. Administrative data offer broad, cost-effective insights but can face data integrity issues. Household surveys, such as DHS and MICS, provide detailed insights, with innovations like MICS Plus harnessing digital technology for real-time data collection. An industrial quality control methodology, LQAS, enables rapid regional assessments, while school-based methods leverage educational infrastructure but may have limited scope. Serosurveys stand out in terms of technical rigor, emphasizing effective vaccination coverage, although these are not spared from challenges linked to biological sampling. Thus, the integration of LQAS with household surveys, particularly when extended with the MICS Plus model, can furnish comprehensive and timely data, proving especially beneficial for developing countries. Furthermore, school-based assessments can effectively bridge data disparities in regions with robust educational infrastructure if harmonized with other methodologies such as serosurveys. Thus, this review offers a contemporary guide for policymakers, health professionals, and program implementers to adopt flexible approaches in the future.

Author's Contribution:

Concept & Design of Study:	Sundeep Sahitia
Drafting:	Idayu Badilla Idris, Nazarudin Safian
Data Analysis:	Khadijah Shamsuddin, Rozita Hod
Revisiting Critically:	Sundeep Sahitia, Idayu Badilla Idris
Final Approval of version:	Sundeep Sahitia

Conflict of Interest: The study has no conflict of interest to declare by any author.

Source of Funding: None

REFERENCES

1. Offit PA. Vaccine History: Developments by Year 2023 [Available from: https://www.chop.edu/centers-programs/vaccine-education-center/vaccine-history/developments-by-year.
2. Antonelli-Incalzi R, Blasi F, Conversano M, Gabutti G, Giuffrida S, Maggi S, et al. Manifesto on the Value of Adult Immunization: "We Know, We Intend, We Advocate". Vaccines (Basel) 2021;9(11).
3. Serratos-Sotelo L. Were there long-term economic effects of exposure to polio vaccination? An analysis of migrants to Sweden 1946-2003. SSM Popul Health 2020;11:100589.
4. Oskorouchi HR, Sousa-Poza A, Bloom DE. The long-term cognitive and schooling effects of childhood vaccinations in China. NBER Working Paper Series. Working Paper 27217. Cambridge (MA): National Bureau of Economic Research; 2020 May. Available from: http://www.nber.org/papers/w27217.
5. Decouttere C, De Boeck K, Vandaele N. Advancing sustainable development goals through immunization: a literature review. Global Health 2021;17(1):95.
6. World Health Organization. Immunization coverage [Internet]. Geneva: World Health Organization; 2023 Jul 18. Available from: https://www.who.int/news-room/fact-sheets/detail/immunization-coverage.
7. Lenart C, Prager M, Sachs M, Steininger C, Fernandes C, Thannesberger J. Tackling Vaccine Hesitancy and Increasing Vaccine Willingness Among Parents of Unvaccinated Children in Austria. Int J Public Health 2023;68:1606042.
8. Ahmad N, Din IAM, Idris IB, Zaini NE. Resurgence of measles infection among children: findings from a surveillance-based population study. Paediatrica Indonesiana 2023;63(3):162-8.
9. Cutts FT, Claquin P, Danovaro-Holliday MC, Rhoda DA. Monitoring vaccination coverage: Defining the role of surveys. Vaccine 2016;34(35):4103-9.
10. MacNeil A, Lee CW, Dietz V. Issues and considerations in the use of serologic biomarkers for classifying vaccination history in household surveys. Vaccine 2014;32(39):4893-900.
11. Bosch-Capblanch X, Ronveaux O, Doyle V, Remedios V, Bchir A. Accuracy and quality of immunization information systems in forty-one low income countries. Trop Med Int Health 2009;14(1):2-10.
12. Groom H, Hopkins DP, Pabst LJ, Murphy Morgan J, Patel M, Calonge N, et al. Immunization information systems to increase vaccination rates: a community guide systematic review. J Public Health Manag Pract 2015;21(3):227-48.
13. Rau C, Ludecke D, Dumolard LB, Grevendonk J, Wiernik BM, Kobbe R, et al. Data quality of reported child immunization coverage in 194 countries between 2000 and 2019. PLOS Glob Public Health 2022; 2(2):e0000140.

14. Bloland P, MacNeil A. Defining & assessing the quality, usability, and utilization of immunization data. BMC Public Health 2019;19(1):380.
15. Corsi DJ, Neuman M, Finlay JE, Subramanian SV. Demographic and health surveys: a profile. Int J Epidemiol 2012;41(6):1602-13.
16. Rutstein SO, Rojas G. Guide to DHS Statistics [Internet]. Calverton (MD): ORC Macro, Demographic and Health Surveys; 2003 Sep. Available from: https://pdf.usaid.gov/ pdf_docs/ Pnacy778.pdf.
17. Dimitrova A, Carrasco-Escobar G, Richardson R, Benmarhnia T. Essential childhood immunization in 43 low- and middle-income countries: Analysis of spatial trends and socioeconomic inequalities in vaccine coverage. PLoS Med 2023;20(1): e1004166.
18. Shane Khan, Hancioglu A. Multiple Indicator Cluster Surveys: Delivering Robust Data on Children and Women across the Globe. Studies Family Planning 2019;50.
19. UNICEF. Innovations in household surveys: MICS Plus as a longitudinal real-time data collection tool March 2021 [Available from: https://mics. unicef.org/mics-plus/methodology-and-use.
20. Biedron C, Pagano M, Hedt BL, Kilian A, Ratcliffe A, Mabunda S, et al. An assessment of Lot Quality Assurance Sampling to evaluate malaria outcome indicators: extending malaria indicator surveys. Int J Epidemiol 2010;39(1):72-9.
21. Alberti KP, Guthmann JP, Fermon F, Nargaye KD, Grais RF. Use of Lot Quality Assurance Sampling (LQAS) to estimate vaccination coverage helps guide future vaccination efforts. Trans R Soc Trop Med Hyg 2008;102(3):251-4.
22. Rhoda DA, Prier ML, Clary CB, Trimner MK, Velandia-Gonzalez M, Danovaro-Holliday MC, et al. Using Household Surveys to Assess Missed Opportunities for Simultaneous Vaccination: Longitudinal Examples from Colombia and Nigeria. Vaccines (Basel) 2021;9(7).
23. Mellerson JL, Maxwell CB, Knighton CL, Kriss JL, Seither R, Black CL. Vaccination coverage for selected vaccines and exemption rates among children in kindergarten - United States, 2017-18 School Year. MMWR Morb Mortal Wkly Rep 2018;67(40):1115-1122.
24. Seither R, McGill MT, Kriss JL, Mellerson JL, Loretan C, Driver K, et al. Vaccination coverage with selected vaccines and exemption rates among children in kindergarten - United States, 2019-20 School Year. MMWR Morb Mortal Wkly Rep 2021;70(3):75-82.
25. Bethke N, Gellert P, Knoll N, Weber N, Seybold J. A school-based educational on-site vaccination intervention for adolescents in an urban area in Germany: feasibility and psychometric properties of instruments in a pilot study. BMC Public Health 2022;22(1):60.
26. Greyson D, Vriesema-Magnuson C, Bettinger JA. Impact of school vaccination mandates on pediatric vaccination coverage: a systematic review. CMAJ Open 2019;7(3):E524-E36.
27. Hill HA, Elam-Evans LD, Yankey D, Singleton JA, Dietz V. Vaccination coverage among children aged 19–35 months — United States, 2015. Morb Mortal Wkly Rep 2016;65(39):1065–1071.
28. Sarah E. Wilson SLD, Todd F. Hatchette, Natasha S. Crowcroft. The role of seroepidemiology in the comprehensive surveillance of vaccine-preventable diseases. CMAJ 2012;184(1).
29. Wanjiku HW, Adetifa IMO. Serological Surveys for complementing assessments of vaccination coverage in sub-Saharan Africa: A systematic review. Wellcome Open Res 2018;3.
30. Hancioglu A, Arnold F. Measuring coverage in MNCH: tracking progress in health for women and children using DHS and MICS household surveys. PLoS Med 2013;10(5):e1001391.
31. Rhoda DA, Fernandez SA, Fitch DJ, Lemeshow S. LQAS: User Beware. Int J Epidemiol 2010; 39(1):60-8.
32. Berti PR, Nardocci M, Tran MH, Batal M, Brodmann R, Greliche N, et al. Using DHS and MICS data to complement or replace NGO baseline health data: an exploratory study. F1000 Res 2021;10:69.
33. Duarte BPM. A systematic approach for designing Bayesian-Lot Quality Assurance Sampling plans. Operations Research for Health Care 2018;19: 175-84.