BMJ Open

Vaccination Assessments using the Demographic and Health Survey, 2005-2018; A Scoping Review

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-039693
Article Type:	Original research
Date Submitted by the Author:	23-Apr-2020
Complete List of Authors:	Shenton, Luke; University of Michigan, Epidemiology Wagner, Abram; University of Michigan, Epidemiology Ji, Mengdi; University of Michigan, Epidemiology Carlson, Bradley; University of Michigan, Epidemiology Boulton, Matthew; University of Michigan,
Keywords:	Paediatric infectious disease & immunisation < PAEDIATRICS, Public health < INFECTIOUS DISEASES, International health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Vaccination Assessments using the Demographic and Health Survey, 2005-2018; A Scoping Review

Luke M. Shenton (lshenton@umich.edu) [1,*]
Abram L. Wagner (awag@umich.edu) [1,*,†]
Mengdi Ji (mengdiji@umich.edu) [1]
Bradley F. Carlson (bcarlson@umich.edu) [1]
Matthew L. Boulton (mboulton@umich.edu) [1,2]

[1] Department of Epidemiology, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor, MI 48109, USA

[2] Department of Internal Medicine, Division of Infectious Disease, University of Michigan Medical School, 1500 East Medical Center Drive, Ann Arbor, MI 48109, USA

* Equal contributors

† **Address correspondence to:**
Abram L. Wagner, 1415 Washington Heights, Ann Arbor, MI 48109, USA [awag@umich.edu]
TEL: +001-734-763-2330 FAX: +001-734- 647-1120

Running Head: Scoping review of vaccination assessments

Word Count: 3,608 **Abstract:** 279

ABSTRACT

Objective: To characterize studies which have used DHS datasets to evaluate vaccination status.

Design: Scoping review

Data sources: Electronic databases including PubMed, EBSCOhost, and POPLINE, from 2005-2018

Study selection: All English studies with vaccination status as the outcome and the use of Demographic and Health Survey (DHS) data.

Data extraction: Studies were selected using a predetermined list of eligibility criteria and data was extracted independently by two authors. Data related to the study population, the outcome of interest (vaccination), and commonly seen predictors were extracted.

Results: A total of 125 articles were identified for inclusion in the review. The number of countries covered by individual studies varied widely (1 to 86), with the most published papers using data from India, Nigeria, Pakistan, and Ethiopia. Many different definitions of full vaccination were utilized although the majority used a traditional schedule recommended in the WHO's Expanded Program on Immunization. We found studies analyzed a wide variety of predictors, but the most common were maternal education, wealth, urbanicity, and child's sex. Most commonly reported predictors had consistent relationships with the vaccination outcome, outside of sibling composition.

Conclusions: Researchers make frequent use of the DHS dataset to describe vaccination patterns within one or more countries. A clearer idea of past use of DHS can inform the development of more rigorous studies in the future. Researchers should carefully consider whether a variable needs to be included in the multivariable model, or if there are mediating relationships across predictor variables.

Keywords: vaccine-preventable diseases; developing countries; immunization programs; surveys and questionnaires

Strengths and limitations

- The Demographic and Health Surveys (DHS) are some of the most used sources of national-level vaccination data
- Most DHS studies find consistent relationships between sociodemographic variables and vaccination outcomes.
- There are large variations in how often a country's DHS dataset is used.
- A limitation is the use only of English language material.
- Other national-level vaccination surveys are also used.

INTRODUCTION

Vaccinations have been a cost-effective method to control and achieve elimination and eradication of common and sometimes deadly infectious diseases [1]. The introduction of routine vaccinations in the United States, for example, has led to a >90% decline in cases of diphtheria, measles, mumps, pertussis, polio, rubella, smallpox, and tetanus since the prevaccine era [2]. Nevertheless, every year, more than 2.7 million individuals die from acute diseases caused by common vaccine-preventable diseases [3]. The overwhelming majority of vaccine-preventable deaths among children <5 years occur in low- and middle-income countries [4].

Based on the prevalence and severity of disease and on the availability of a safe and effective vaccine, the World Health Organization (WHO) recommends that countries include nine vaccines on their publicly funded vaccine schedule for young children [5]. Referred to as the Expanded Program on Immunization (**EPI**), the schedule initially recommended vaccination with Bacillus Calmette-Guérin (BCG), diphtheria-tetanus-pertussis vaccine (DTP), polio vaccine, and a measles-containing vaccine (MCV). Since 2004, five additional pediatric vaccines have been added to the WHO EPI: hepatitis B vaccine (HepB), *Haemophilus influenzae* type b vaccine (Hib), rubella vaccine, pneumococcal conjugate vaccine (PCV), and rotavirus vaccine. Individual countries decide which vaccines to publicly fund and also to make available on the private market resulting in wide variation globally in the adoption of these vaccines. For example, in 2015, 194 countries included 3 doses of DTP and polio in their immunization schedule whereas only 84 included rotavirus [6]. Many countries now use a pentavalent vaccine, which includes DTP, HepB, and Hib vaccines in one vial. Substantial efforts on the part of the GAVI Alliance and other international agencies are devoted to logistically and financially supporting the introduction of new and underused vaccines [7]. These efforts are particularly important because a discouragingly high number of children consistently do not receive some or all of the vaccines that were first recommended by the WHO. According to the WHO, 19.4 million children have not received three doses of DTP, with a majority (11.7 million) living in just 10 countries: Nigeria, India, Pakistan, Indonesia, Ethiopia, Philippines, the Democratic Republic of the Congo, Brazil, Angola, and Vietnam [8]. With the exception of Brazil, all of these countries have vaccination coverage regularly assessed as part of the Demographic and Health Survey (DHS) program.

Nationally representative surveys, like those of the DHS program, have been essential to evaluating country- and region-specific vaccination program over time. DHS programs are funded and facilitated by the US Agency for International Development (USAID). The DHS program was launched in 1984 with a goal of advancing global understanding of health and population trends in developing countries. Since its inception it has provided technical assistance for over 300 surveys in 93 developing countries across the globe. Today, the program is known for collecting and disseminating accurate, nationally representative data on a variety of topics including fertility, family planning, maternal and child health, gender, HIV/AIDS, malaria, and nutrition. Host countries have ownership of data collection, analysis, presentation,

and use and the data is designed to ultimately be used in policy formation, program planning, and monitoring and evaluation [9].

A large number of prior studies have amalgamated data from several different DHS datasets, or have included data from many countries, but none has systematically evaluated how these past studies have actually used the vaccination data provided by DHS [10–12]. Given that DHS has had widespread use over several decades in evaluating vaccination programs through identification of under-vaccinated groups, and characterizing systematic barriers to vaccination, a clearer idea of past use of DHS can inform the development of more rigorous studies in the future. The purpose of this scoping review was to characterize studies which have used DHS datasets to evaluate vaccination status. Specifically we look at the global and temporal distribution of studies, list the predictors used in multivariable regression models, and examine the different definitions of "full vaccination" and how these relate to the WHO EPI recommendations

METHODS

This scoping review was completed by following the steps outlined by the Preferred Reporting Items of Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) [13].

Search Strategies

Searches were performed in 3 different electronic databases: PubMed/MEDLINE, PopLine, and EBSCOhost's Africa-Wide Information, Global Health, Global Health Archives, and Health Policy Reference Center databases. The search terms used were; "Vaccine" (and its variations such as vaccination and vaccinate), "Immunization" (and its variations such as immunize), "demographic and health surveys", "demographic and health survey", "DHS", "National Family Health Survey", and "NFHS". In addition, the searches were limited to only return papers published between 1 January 2005 and 31 December 2018. References from articles found to be relevant were searched in order to identify additional articles.

Eligibility Criteria

The titles of all papers returned through use of the search terms were initially screened for relevance. The abstracts of all remaining papers were then accessed with specific inclusion and exclusion criteria in mind. Abstracts and manuscripts were included if they met all inclusion criteria: (1) studies were conducted using DHS data from low or middle-income countries; (2) studies looked at routine vaccination coverage as the primary outcome; (3) studies were cross-sectional in design; (4) studies used either the Demographic and Health Survey (DHS) or the National Family Health Survey (NFHS), a similar study conducted only in India; (5) studies looked specifically at the vaccination outcome of children (usually aged between 0 and 60 months). A set of exclusion criteria was also created: (1) studies published before 2005 or after 2018 (though studies with an online publication in 2018 but print publication in 2019 were included); (2) studies that looked only at the vaccination outcome of adults; (3) studies that

looked at population in high income countries; (4) studies that used modeling or projections instead of just analyzing the data provided; or (5) systematic reviews.

Study Selection

LS removed all duplicate and assessed all titles for relevance. Then three reviewers (LS/BC/AW) independently assessed all abstracts and full-text publications for eligibility using the eligibility criteria laid out. All disagreements were resolved by discussion between reviewers.

Data extraction

In addition to assessment for relevance, data was also extracted independently by three reviewers (LS/BC/AW). A data extraction form was designed using Google Sheets and was piloted before beginning data extraction. Data from 3 main categories was gathered during data extraction. The first area was the study population, including the countries of interest, the subpopulation of children being examined, years of the survey administration, and whether any surveys besides DHS or NFHS were used. The second category was the outcome of interests: which individual vaccines were assessed, whether full or under vaccination was examined, and if full or under vaccination was examined how were they defined. Lastly, data on vaccination predictors was gathered. We tabulated whether a given study included the most common predictors found in a previous systematic review of vaccination timeliness [14]: maternal education, wealth index, urbanicity, sex of child, age of mother, birth order, birth delivery location, number of antenatal care (ANC) visits, media exposure, and paternal education.

Study Methodological quality evaluation

We modified the Downs and Black checklist [15] for assessing biases in systematic reviews because all eligible studies used a similar data source. The checklist included the following criteria:

Introduction / Study population

A. Is the hypothesis/aim/objective of the study clearly described? (1=Yes, 0=No)
B. Are the main outcomes (including defining full vaccination, if applicable) to be measured clearly described in the introduction or methods? (1=Yes, 0=No)
C. Are the characteristics of study population eligibility criteria (including age range) clearly described? (1=Yes, 0=No)

Descriptive Statistics

D. Does the paper use weighting and clustering? (1=Yes, 0=No)
E. Does the paper provide estimates of random variability (e.g., 95% confidence interval of weighted estimates or standard errors) for the main outcomes? (1=Yes, 0=No)

Analytical Statistics

F. Does the paper use do a multivariable analysis? (1=Yes, 0=No)
G. Does the paper show distribution of confounders / covariates? (1=Yes, 0=No)
H. Does the paper describe how the researchers arrived at the final list of confounders? (2=*a priori* knowledge or used DAG, 1=used P-values from crude analysis or used stepwise technique, 0=did not describe or did not use multivariable analysis)

I. Does the paper write out P-values under 0.05? (1= Yes, or provided 95% confidence intervals, 0=No)

The quality score could range from 0-10.

Synthesis of study findings

Given the heterogeneity of outcomes, predictors, and study populations of the included studies it was not possible to combine the results into a meta-analysis. Instead, we present a narrative summary of the data. We describe the distribution of studies by population, what predictor variables are used (and what direction of association they have with outcome), and how full vaccination is defined. In the discussion, we provide recommendations for future analyses of DHS data.

A choropleth map was created using freely available shapefiles from Natural Earth [16] in QGIS 3.6 (QGIS Development Team). The map shows how many studies using data from only one country were published by country. We also show if a country's data was part of a multicountry study, and we identify countries which had a standard DHS dataset administered between 2003 and 2016 but which did not have a published study. The years 2003-2016 were chosen as a lag time of 2 years compared to the scoping review inclusion criteria to account for delays in publishing the data and writing up a manuscript.

Patient and public involvement

This research was done without public involvement. Members of the public were not invited to comment on the study design and were not consulted, nor were they invited to contribute to this document to improve accessibility.

RESULTS

Our search terms initially yielded 938 papers; 318 from PubMed, 323 from EBSCOhost, and 211 from POPLINE. An additional 86 papers were identified through searching the references of selected papers. After removing duplicates, 551 papers remained. These papers' abstracts were screened using the inclusion and exclusion criteria to narrow down the study pool to 143 papers. However, during full text screen and data extraction another 18 studies were removed, which left 125 (Figure 1).

The quality sum score (possible range from 0-10) was on average 6.48 with a median of 7. The most commonly missed items contributing to a lower quality sum score were absence of exact P-values or confidence intervals (64% did not), not including estimates of random variability for the outcome (52%), and failure to account for appropriate use of clustering and weights (44%).

DHS has operated in a total of 92 countries since its inception, and between 2003 and 2016, has conducted surveys in 71 different countries.

Overall, 23 studies used DHS datasets from multiple countries, ranging from 2 countries [81,96,107] to 86 countries [11]. Seven studies used data from multiple African countries [56,69,84,98,113,122,123], 4 from just Asian countries [72,81,96,135], 1 from the Americas [107], and the remainder (11) used data from multiple continents [10,11,111,12,21,30,53,74,88,101,104]. For one study, we were unable to determine what exact countries were included in the analysis [111].

Figure 2 is a choropleth map showing which countries' DHS dataset have been used for vaccination studies. The most frequently represented country is India (26 studies, 21%), followed by Nigeria (17, 14%), Ethiopia and Pakistan (7 each, 6%), and Bangladesh (6, 5%). Notably, there are many countries (44) in the Americas, Europe, and Africa, which had one or more DHS conducted between 2003 and 2016 yet for which there are no corresponding single-country papers published using DHS data in this scoping review. However, most of these countries were a part of multicountry studies. Only five countries' DHS datasets were not part of any (single country or multicountry) DHS study: Cabo Verde, Maldives, Morocco, Sri Lanka, and Ukraine.

Characteristics of the papers are shown in Table 1. About half (51%) of studies included children 12 to 23 or 24 months of age, and the two next most common age ranges were 12 to 59 or 60 months of age (11%) and 0 to 59 months of age (8%).

Full vaccination was assessed in three-fourths (94, 75%) of papers; otherwise, the four most common vaccines assessed one at a time were MCV (39, 31%), DTP (36, 29%), polio (33, 26%), and BCG (27, 22%). There were at least 12 different definitions of full vaccination used in the papers including in this scoping review. Of the 94 papers which evaluated full vaccination coverage, most (66, 70%) used a traditional schedule based off of the four vaccines first recommended for the WHO's EPI in 1974: 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose MCV. Five (5%) papers modified this traditional definition to include a birth dose of polio, and eleven others used a pentavalent vaccine instead of DTP (of these, 3 had a 4 dose polio schedule, and 8 had a 3-dose polio schedule). Other papers modified the traditional definition in order to include yellow fever (in a total of 4 papers), measles-mumps-rubella vaccine (in one paper), or to exclude certain vaccine series, like measles, polio, or BCG. Some measure of DTP was included in all definitions of full vaccination. No papers included information about PCV or rotavirus vaccine as an outcome in a multivariable regression model, although one used rotavirus vaccine as a predictor variable [107].

Four variables were used in a majority of studies. The top 10 variables used in a study (with their relationship shown in a model) are maternal education (in 94, or 75% of studies), wealth index (88, 70%), urbanicity (79, 63%), child's sex (73, 58%), mother's age (60, 48%), birth order (51, 41%), delivery location (42, 34%), ANC visits (34, 27%), media exposure (33, 26%), and paternal education (32, 26%).

The relationship between the most commonly used predictor and vaccination outcomes is shown in Figure 3. For most predictors there is a relatively clear relationship to vaccination outcome. For a majority of studies, greater vaccination coverage (across any vaccination outcome considered) was related to maternal education (in 84% of studies that considered the variable), higher wealth index (83%), more ANC visits (76%), greater media exposure (76%), an institutional birth (69%), and more paternal education (56%). For several predictors, a large proportion of studies found no significant relationship. This was especially true for child's sex (66% of studies), more paternal education (44%), and urbanicity (43%). Sibling composition was one variable for which there was no clear relationship with the outcome: in 41% of studies, having more older siblings was associated with lower vaccination coverage, in 8% it was associated with higher vaccination coverage, and for the rest of studies, there was no significant relationship (35%) or there was a significant, non-monotonic relationship (12%).

DISCUSSION

Vaccination programs enjoy wide support from many international health organizations and national governments. Vaccination has achieved the sole instance of human disease eradication – smallpox, while polio, measles, and rubella have been eliminated in some regions of the world [1,139]. Global vaccination coverage has increased in recent years but 12.8 million children in 2015 still had not yet received DTP dose 1 [6], a common marker routine immunization initiation. Regularly conducted studies on vaccination uptake are necessary to assessing population level susceptibility and immunization program reach while also ensuring that countries are on track with international guidelines for maintaining high vaccination coverage and the control or elimination of certain vaccine-preventable diseases. The DHS datasets tend to be very large, both in number of variables looked at and number of participants surveyed. This allows the examination of many possible associations with sufficient statistical power and the ability to control for a number of possible confounders.

DHS is not conducted in all LMICs, only in certain countries with a USAID presence, and it is conducted at irregular intervals. However, it is one of the most widely available surveys for assessing vaccinations globally. This systematic review found wide variation in how full vaccination was defined across 125 studies using DHS data between 2005 and 2018. However, the majority of studies did look at full vaccination and defined it according to the WHO's EPI schedule; 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose MCV. Additionally, studies looked at similar sub-populations (children <5) and very similar predictors, with the most common being maternal education, wealth, urbanicity, and child's sex.

The vaccines commonly evaluated reflect priorities of international efforts. For example, polio is targeted for elimination by 2018 [140]. Measles is also subject to an international elimination effort [141,142], and all 6 WHO regional offices have established target dates for elimination [143]. BCG was one of the first vaccines ideally administered shortly after birth (joined more recently in certain locations with HepB and polio birth doses). And DTP dose 3 has long been used as a proxy for adherence to repeat visits to immunization appointments [144,145]. As more

vaccines are added to the vaccine schedule, not only does it become more complicated, but it likely introduces the potential j for greater diversity among countries in their respective EPI schedules. Over the past few decades, DHS has operated in 92 countries. However, a significant number of papers came from a relatively small number of countries. We note the most commonly used countries (India, Nigeria, Ethiopia, Pakistan, and Bangladesh) are among the 12 most populous countries in the world, and, with the exception of Bangladesh, are among the five countries with the most number of unvaccinated children [8]. Given that countries have control over their own vaccine policies and utilize a wide variety of socioeconomic variables across individual countries, more country-specific analyses of DHS vaccination data is important.

Recommendations for future analyses

This study identified the variables commonly used as explanatory variables in multivariable regression models. Many studies appeared to use the DHS datasets to test the significance and estimate the strength of association for many explanatory variables concomitantly. Since DHS is a cross-sectional study it cannot be used to look at causal associations between variables. However, a strength of DHS is its ability to be used as a hypothesis generating device. Associations can subsequently be examined in other types of studies, such as cohort studies.

However, given consistent relationships between commonly used predictors and outcomes, it is worth revisiting the use of DHS datasets in multivariable analyses. First, given this consistency, it is more important than ever to consider the plausible causal relationships across all variables utilized in a model. An approach widely used in epidemiology is to chart the directionality of relationships among variables through directed acyclic graphs (DAGs) [146]. Online software, like dagitty.net, can be used to build these models and assess which variables should be included in the final multivariable model. A potential problem is inclusion of so many variables in one model can obscure the mediating effects of certain variables [147]. For example, researchers examining the relationship between media exposure and vaccination status may include maternal age as a confounder. However, the parameter estimate for maternal age in this multivariable model includes the mediator media exposure. Theoretically, a model with age as the main predictor and with media exposure as a main predictor would have different sets of covariates. Although the potential impact of inappropriately controlling for mediation is context-specific, one study suggests parameter estimates may change up to 10%-25% [148].

Evolving immunization schedules mean that future studies will likely take local programmatic considerations into account. However, to make cross country comparisons, studies could still provide an estimate of full vaccination using the traditional BCG, 3 dose polio, 3 dose DTP, and 1 dose MCV schedule.

Timeliness has also emerged as an important dimension of vaccination uptake within the past two decades [149,150]. Measures of timeliness require vaccination dates [14], information missing from many individuals in the DHS datasets. For example, in the 2006-2007 Pakistan

DHS EPI immunization cards, and thus data on vaccination dates, were available for just 10% of cases [85].

Finally, researchers analyzing DHS data should be aware of its structure and limitations. Most DHS samples are stratified and based on clusters. Studies should use survey procedures and weights to ensure that estimates are representative of the national population and that standard errors are honest reflections of the sampling structure. Additionally, because DHS includes so many individuals with unknown vaccination age, any study should account for this substantial left censoring, through Turnbull estimation methods [151] or accelerated failure time models. A substantial minority of studies examined did not specify the age range of the study population. This has implications for timeliness but should be presented in studies calculating more traditional measures of vaccine uptake that do not incorporate timing or age.

The DHS provides national estimates from politically neutral sources, in countries where USAID operates. Its continued existence ensures that reliable and nationally representative data sources are publicly available. Although other surveys, like the District Level Household Survey (DLHS) and the Annual Health Survey (AHS) in India and the Multiple Indicators Cluster Survey (MICS) in over 100 countries, are not funded by USAID [152,153].

Limitations

There are several limitations to this study. Because the study populations, use of explanatory variables, and definitions of outcomes differed among studies, we were unable to conduct a meta-analysis to compare the association of various explanatory variables on outcomes. We did not examine the grey literature or non-English language papers as part of this review, nor did we review reports which may have listed vaccination coverage, but did not include some statistical analysis. Inclusion of these types of articles could have included data from more countries. Vaccination data from the DHS is limited in that it partially comes from information contained on vaccination cards [154], and partially from parental recall – with its obvious potential for errors. However, some countries, such as Ethiopia, have attempted to combat this problem in recent years through the introduction of a Health Facility Questionnaire. This questionnaire is used to record vaccination information for all children, who were discovered to not have a vaccination card during administration of the Woman's Questionnaire [155]. In addition, since the DHS is a standardized questionnaire there is limited opportunity to modify the survey to be locally relevant and take predictors into account that may only be relevant in parts of the country. However, overall the DHS programs are widely available surveys providing researchers, policymakers, and the public with nationally representative data. These data provide a basis for evaluation of immunization programs that would either not exist or not be as robust in their absence.

Conclusions

This scoping review of papers about vaccination published using DHS data found diversity in analyses and qualities of studies. Although certain countries – like India, Nigeria, Pakistan, and Ethiopia – have had ≥7 vaccination studies published using DHS data, there are dozens of countries whose vaccination data have not yet been published within single-country studies. Studies find consistent relationships between greater vaccination uptake and more maternal education, higher wealth index, more ANC visits, greater media exposure, and institutional delivery. The relationship between birth order and vaccination status is more varied across countries. Researchers using the DHS datasets should understand the limitations of using recorded vaccination dates, and should clarify the interpretation of estimates from multivariable analyses given the potential for mediation.

Acknowledgements

We are grateful to the DHS personnel who diligently carry out their work and to USAID for sponsoring the DHS projects.

Funding

We report no external funding.

Competing Interests

The authors declare no competing interests.

Author contributions

MLB conceived of the study design, helped interpret the data, and revised the manuscript critically for important intellectual content. LMS and BFC downloaded manuscripts, assessed their fit for this systematic review, abstracted data from the manuscripts, completed qualitative synthesis, and helped revise the manuscript critically for important intellectual content. MJ abstracted data from the manuscripts and helped revise the manuscript critically for important intellectual content. ALW helped interpret the data, and drafted the article. All authors gave final approval of the manuscript to be published.

Data sharing statement

The data abstracted from these studies are publicly available: https://doi.org/10.6084/m9.figshare.12177135

REFERENCES

1 Centers for Disease Control and Prevention. Ten great public health achievements, 1900–1999: impact of vaccines universally recommended for children. *Morb Mortal Wkly Rep* 1999;**48**:243–8.

2 Roush SW, Murphy T V. Historical comparisons of morbidity and mortality for vaccine-preventable diseases in the United States. *JAMA* 2007;**298**:2155–63. doi:10.1001/jama.298.18.2155

3 Lozano R, Naghavi M, Foreman K, *et al.* Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**:2095–128. doi:10.1016/S0140-6736(12)61728-0

4 Black RE, Cousens S, Johnson HL, *et al.* Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet (London, England)* 2010;**375**:1969–87. doi:10.1016/S0140-6736(10)60549-1

5 World Health Organization. Summary of WHO Position Papers - Recommendations for Routine Immunization. 2017.http://www.who.int/immunization/policy/Immunization_routine_table1.pdf (accessed 7 Sep 2017).

6 Casey RM, Dumolard L, Danovaro-Holliday MC, *et al.* Global Routine Vaccination Coverage, 2015. *Morb Mortal Wkly Rep* 2016;**65**:1270–3.

7 GAVI Alliance. Vaccine goal indicators. GAVI. 2015.http://www.gavi.org/results/goal-level-indicators/vaccine-goal-indicators/ (accessed 2 Jun 2016).

8 Peck M, Gacic-Dobo M, Diallo MS, *et al.* Global routine vaccination coverage, 2018. *Morb Mortal Wkly Rep* 2019;**68**:937–42. doi:10.15585/mmwr.mm6645a3

9 The DHS Program. The DHS Program: Demographic and Health Surveys. 2017.https://dhsprogram.com/ (accessed 3 Oct 2017).

10 Arsenault C, Johri M, Nandi A, *et al.* Country-level predictors of vaccination coverage and inequalities in Gavi-supported countries. *Vaccine* 2017;**35**:2479–88. doi:10.1016/j.vaccine.2017.03.029

11 Restrepo-Méndez MC, Barros AJD, Wong KLM, *et al.* Inequalities in full immunization coverage : trends in low- and middle-income countries. *Bull World Heal Organ* 2016;**94**:794–805. doi:10.2471/BLT.15.162172

12 Restrepo-Méndez MC, Barros AJD, Wong KLM, *et al.* Missed opportunities in full immunization coverage: Findings from low- and lower-middle-income countries. *Glob Health Action* 2016;**9**:1–6. doi:10.3402/gha.v9.30963

13 Moher D, Liberati A, Tetzlaff J, *et al.* Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009;**151**:264–9, W64.

14 Masters NB, Wagner AL, Boulton ML. Vaccination timeliness in low- and middle-income countries: a systematic review of the literature, 2007-2017. *Hum Vaccin Immunother* 2019;**15**:2790–805. doi:10.1080/21645515.2019.1616503

15 Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Heal* 1998;**52**:377–84.

16 Natural Earth. Admin 0 - Countries. 2020.https://www.naturalearthdata.com/downloads/50m-cultural-vectors/50m-admin-0-countries-2/ (accessed 30 Mar 2020).
17 Bowie C, Mathanga D, Misiri H. Poverty, access and immunization in Malawi - a descriptive study. Malawi Med. J. 2006;**18**:19–27. doi:10.4314/mmj.v18i1.10902
18 Choi JY, Lee S-H. Does prenatal care increase access to child immunization? Gender bias among children in India. *Soc Sci Med* 2006;**63**:107–17. doi:10.1016/j.socscimed.2005.11.063
19 Gaudin S, Yazbeck AS. Immunization in india 1993-1999: Wealth, gender, and regional inequalities revisited. *Soc Sci Med* 2006;**62**:694–706. doi:10.1016/j.socscimed.2005.06.042
20 Akmatov MK, Kretzschmar M, Krämer A, *et al.* Determinants of childhood vaccination coverage in Kazakhstan in a period of societal change: Implications for vaccination policies. *Vaccine* 2007;**25**:1756–63. doi:10.1016/j.vaccine.2006.11.030
21 Anand S, Bärnighausen T. Health workers and vaccination coverage in developing countries: an econometric analysis. *Lancet* 2007;**369**:1277–85. doi:10.1016/S0140-6736(07)60599-6
22 Bhandari P, Shrestha SS, Ghimire DJ. Sociocultural and geographical disparities in child immunization in Nepal. *Asia-Pacific Popul J* 2007;**22**:43–64.
23 Datar A, Mukherji A, Sood N. Health infrastructure & immunization coverage in rural India. *Indian J Med Res* 2007;**125**:31–42.
24 Minh Thang N, Bhushan I, Bloom E, *et al.* Child immunization in Vietnam: situation and barriers to coverage. *J Biosoc Sci* 2007;**39**:41–58. doi:10.1017/S0021932006001234
25 Munthali AC. Determinants of vaccination coverage in Malawi: evidence from the demographic and health surveys. *Malawi Med J* 2007;**19**:79–82. doi:10.4314/mmj.v19i2.10934
26 Ntenda PAM, Chuang K-Y, Tiruneh FN, *et al.* Analysis of the effects of individual and community level factors on childhood immunization in Malawi. *Vaccine* Published Online First: 2017. doi:10.1016/j.vaccine.2017.02.036
27 Chidiebere ODI, Uchenna E, Kenechi OS. Maternal sociodemographic factors that influence full child immunisation uptake in Nigeria. *SAJCH South African J Child Heal* 2014;**8**:138–42. doi:10.7196/SAJCH.661
28 Gatchell M, Thind A, Hagigi F. Informing state-level health policy in India: The case of childhood immunizations in Maharashtra and Bihar. *Acta Paediatr Int J Paediatr* 2008;**97**:124–6. doi:10.1111/j.1651-2227.2007.00569.x
29 Halder AK, Kabir M. Inequalities in infant immunization coverage in Bangladesh. *Heal Serv Insights* 2008;**1**:5–11.
30 Meheus F, Van Doorslaer E. Achieving better measles immunization in developing countries: does higher coverage imply lower inequality? *Soc Sci Med* 2008;**66**:1709–18. doi:10.1016/j.socscimed.2007.12.036
31 Patra N. Exploring the Determinants of Childhood Immunisation. *Econ Polit Wkly* 2008;**43**:97–104.
32 Antai D. Inequitable childhood immunization uptake in Nigeria: a multilevel analysis of individual and contextual determinants. *BMC Infect Dis* 2009;**9**:181. doi:10.1186/1471-2334-9-181

33 Antai D. Faith and Child Survival: the Role of Religion in Childhood Immunization in Nigeria. *J Biosoc Sci* 2009;**41**:57. doi:10.1017/S0021932008002861

34 Bondy JN, Thind A, Koval JJ, *et al.* Identifying the determinants of childhood immunization in the Philippines. *Vaccine* 2009;**27**:169–75. doi:10.1016/j.vaccine.2008.08.042

35 Corsi DJ, Bassani DG, Kumar R, *et al.* Gender inequity and age-appropriate immunization coverage in India from 1992 to 2006. *BMC Int Health Hum Rights* 2009;**9 Suppl 1**:S3. doi:10.1186/1472-698X-9-S1-S3

36 Osaki K, Hattori T, Kosen S, *et al.* Investment in home-based maternal, newborn and child health records improves immunization coverage in Indonesia. *Trans R Soc Trop Med Hyg* 2009;**103**:846–8. doi:10.1016/j.trstmh.2009.03.011

37 Sia D, Fournier P, Kobiané J-F, *et al.* Rates of coverage and determinants of complete vaccination of children in rural areas of Burkina Faso (1998-2003). *BMC Public Health* 2009;**9**:416. doi:10.1186/1471-2458-9-416

38 Antai D. Migration and child immunization in Nigeria: individual- and community-level contexts. *BMC Public Health* 2010;**10**:116. doi:10.1186/1471-2458-10-116

39 Hong R, Chhea V. Trend and inequality in immunization dropout among young children in Cambodia. *Matern Child Health J* 2010;**14**:446–52. doi:10.1007/s10995-009-0466-1

40 Rahman M, Obaida-Nasrin S. Factors affecting acceptance of complete immunization coverage of children under five years in rural Bangladesh. *Salud Publica Mex* 2010;**52**:134–40. doi:10.1590/S0036-36342010000200005

41 Sahu D, Pradhan J, Jayachandran V, *et al.* Why immunization coverage fails to catch up in India? A community-based analysis. *Child Care Health Dev* 2010;**36**:332–9. doi:10.1111/j.1365-2214.2009.01003.x

42 Semali IA. Trends in immunization completion and disparities in the context of health reforms: the case study of Tanzania. *BMC Health Serv Res* 2010;**10**:299. doi:10.1186/1472-6963-10-299

43 Abuya BA, Onsomu EO, Kimani JK, *et al.* Influence of maternal education on child immunization and stunting in Kenya. *Matern Child Health J* 2011;**15**:1389–99. doi:10.1007/s10995-010-0670-z

44 Antai D. Rural-urban inequities in childhood immunisation in Nigeria: The role of community contexts. *African J Prim Heal Care Fam Med* 2011;**3**. doi:10.4102/phcfm.v3i1.238

45 Fernandez RC, Awofeso N, Rammohan A. Determinants of apparent rural-urban differentials in measles vaccination uptake in Indonesia. *Rural Remote Health* 2011;**11**:1–14.

46 Fernandez R, Rammohan A, Awofeso N. Correlates of first dose of measles vaccination delivery and uptake in Indonesia. *Asian Pac J Trop Med* 2011;**4**:140–5. doi:10.1016/S1995-7645(11)60055-2

47 Kumar A, Mohanty SK. Socio-economic differentials in childhood immunization in India, 1992-2006. *J Popul Res* 2011;**28**:301–24.

48 Lauridsen J, Pradhan J, Kruk M, *et al.* Socio-economic inequality of immunization coverage in India. *Health Econ Rev* 2011;**1**:11. doi:10.1186/2191-1991-1-11

49 Pandey S. Determinants of child immunization in Nepal : The role of women ' s empowerment. *Health Educ J* 2011;**71**:642–53. doi:10.1177/0017896911419343

50 Singh A. Inequality of Opportunity in Indian Children: The Case of Immunization and

Nutrition. *Popul Res Policy Rev* 2011;**30**:861–83. doi:10.1007/s11113-011-9214-5
51 Afzal N, Zainab B. Determinants and Status of Vaccination in Bangladesh. *Dhaka Univ J Sci* 2012;**60**:47–51. doi:10.3329/dujs.v60i1.10336
52 Antai D. Gender inequities, relationship power, and childhood immunization uptake in Nigeria: A population-based cross-sectional study. *Int J Infect Dis* 2012;**16**:e136–45. doi:10.1016/j.ijid.2011.11.004
53 Rammohan A, Awofeso N, Fernandez RC. Paternal education status significantly influences infants' measles vaccination uptake, independent of maternal education status. *BMC Public Health* 2012;**12**:336. doi:10.1186/1471-2458-12-336
54 Sabarwal S, McCormick MC, Silverman JG, *et al.* Association between maternal intimate partner violence victimization and childhood immunization in India. *J Trop Pediatr* 2012;**58**:107–13. doi:10.1093/tropej/fmr052
55 Singh A. Gender based within-household inequality in childhood immunization in India: Changes over time and across regions. *PLoS One* 2012;**7**:e33045. doi:10.1371/journal.pone.0035045
56 Wiysonge CS, Uthman OA, Ndumbe PM, *et al.* Individual and contextual factors associated with low childhood immunisation coverage in Sub-Saharan Africa: A multilevel analysis. *PLoS One* 2012;**7**. doi:10.1371/journal.pone.0037905
57 Barman D, Dutta A. Access and barriers to immunization in West Bengal, India: Quality matters. *J Heal Popul Nutr* 2013;**31**:510–22.
58 Bbaale E. Factors influencing childhood immunization in Uganda. *J Heal Popul Nutr* 2013;**31**:118–27. doi:10.3329/jhpn.v31i1.14756
59 Haque SMR, Bari W. Positive Role of Maternal Education on Measles Vaccination Coverage in Bangladesh. *Int J Psychol Behav Sci* 2013;**3**:11–7. doi:10.5923/j.ijpbs.20130301.02
60 Kumar A, Ram F. Influence of Family Structure on Child Health: Evidence From India. *J Biosoc Sci* 2013;**45**:577–99. doi:10.1017/S0021932012000764
61 Moyer CA, Tadesse L, Fisseha S. The relationship between facility delivery and infant immunization in Ethiopia. *Int J Gynecol Obstet* 2013;**123**:217–20. doi:10.1016/j.ijgo.2013.06.030
62 Singh A, Singh A, Mahapatra B. The consequences of unintended pregnancy for maternal and child health in rural India: Evidence from prospective data. *Matern Child Health J* 2013;**17**:493–500. doi:10.1007/s10995-012-1023-x
63 Singh K, Haney E, Olorunsaiye C. Maternal autonomy and attitudes towards gender norms: Associations with childhood immunization in Nigeria. *Matern Child Health J* 2013;**17**:837–41. doi:10.1007/s10995-012-1060-5
64 Singh PK. Trends in Child Immunization across Geographical Regions in India: Focus on Urban-Rural and Gender Differentials. *PLoS One* 2013;**8**. doi:10.1371/journal.pone.0073102
65 Van Malderen C, Ogali I, Khasakhala A, *et al.* Decomposing Kenyan socio-economic inequalities in skilled birth attendance and measles immunization. *Int J Equity Health* 2013;**12**:3. doi:10.1186/1475-9276-12-3
66 Adegboye O, Kotze D, Adegboye O. Multi-Year Trend Analysis of Childhood Immunization Uptake and Coverage in Nigeria. *J Biosoc Sci* 2014;**46**:225–39.

doi:10.1017/S0021932013000254

67 Bonfrer I, Van de Poel E, Van Doorslaer E. The effects of performance incentives on the utilization and quality of maternal and child care in Burundi. *Soc Sci Med* 2014;**123**:96–104. doi:10.1016/j.socscimed.2014.11.004

68 Bugvi AS, Rahat R, Zakar R, *et al.* Factors associated with non-utilization of child immunization in Pakistan: evidence from the Demographic and Health Survey 2006-07. *BMC Public Health* 2014;**14**:232. doi:10.1186/1471-2458-14-232

69 Canavan ME, Sipsma HL, Kassie GM, *et al.* Correlates of complete childhood vaccination in East African countries. *PLoS One* 2014;**9**:1–7. doi:10.1371/journal.pone.0095709

70 Clouston S, Kidman R, Palermo T. Social inequalities in vaccination uptake among children aged 0-59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009. *Vaccine* 2014;**32**:3533–9. doi:10.1016/j.vaccine.2014.04.030

71 Ebot JO. Place Matters : Community Level Effects of Women ' s Autonomy on Ethiopian Children ' s Immunization Status. *Etude la Popul Africaine/African Popul Stud* 2014;**28**:1202–15.

72 Grundy J, Annear P, Chomat AM, *et al.* Improving average health and persisting health inequities - Towards a justice and fairness platform for health policy making in Asia. *Health Policy Plan* 2014;**29**:873–82. doi:10.1093/heapol/czt068

73 Heaton TB, Crookston B, Forste R, *et al.* Inequalities in child health in Bolivia: Has Morales made a difference? *Heal Sociol Rev* 2014;**23**:208–18. doi:10.1080/14461242.2014.11081974

74 Helleringer S, Abdelwahab J, Vandenent M. Polio supplementary immunization activities and equity in access to vaccination: Evidence from the demographic and health surveys. *J Infect Dis* 2014;**210**:S531–9. doi:10.1093/infdis/jiu278

75 Javed SA, Imran W, Haider A, *et al.* Mothers related differentials in childhood immunization uptake in Pakistan. *Res Humanit Soc Sci* 2014;**4**:62–72.

76 Luqman B, Titus Kolawole O. Mothers' health seeking behaviour and socio-economic differentials: A factor analysis of full childhood immunization in South-Western Nigeria. *J Public Heal Epidemiol* 2014;**6**:132–47. doi:10.5897/JPHE2013.0593

77 Malhotra C, Malhotra R, Østbye T, *et al.* Maternal autonomy and child health care utilization in India: Results from the National Family Health Survey. *Asia-Pacific J Public Heal* 2014;**26**:401–13. doi:10.1177/1010539511420418

78 Neupane S, Nwaru BI. Impact of prenatal care utilization on infant care practices in Nepal: A National representative cross-sectional survey. *Eur J Pediatr* 2014;**173**:99–109. doi:10.1007/s00431-013-2136-y

79 Prusty RK, Kumar A. Socioeconomic dynamics of gender disparity in childhood immunization in India, 1992-2006. *PLoS One* 2014;**9**:1992–2006. doi:10.1371/journal.pone.0104598

80 Rai RK, Singh PK, Singh L, *et al.* Individual characteristics and use of maternal and child health services by adolescent mothers in Niger. *Matern Child Health J* 2014;**18**:592–603. doi:10.1007/s10995-013-1276-z

81 Singh PK, Parsuraman S. Sibling composition and child immunization in India and Pakistan, 1990-2007. *World J Pediatr* 2014;**10**:145–50. doi:10.1007/s12519-014-0483-z

82 Singh PK, Parasuraman S, P.K. S, *et al.* 'Looking beyond the male-female dichotomy' - sibling composition and child immunization in India, 1992-2006. *Soc Sci Med* 2014;**107**:145–53. doi:10.1016/j.socscimed.2014.02.017

83 Ushie BA, Fayehun OA, Ugal DB. Trends and patterns of under-5 vaccination in Nigeria, 1990-2008: What manner of progress? *Child Care Health Dev* 2014;**40**:267–74. doi:10.1111/cch.12055

84 Wagner Z, Szilagyi PG, Sood N. Comparative performance of public and private sector delivery of BCG vaccination: Evidence from Sub-Saharan Africa. *Vaccine* 2014;**32**:4522–8. doi:10.1016/j.vaccine.2014.06.020

85 Zaidi SMA, Khowaja S, Dharma VK, *et al.* Coverage, timeliness, and determinants of immunization completion in Pakistan: Evidence from the Demographic and Health Survey (2006-07). *Hum Vaccines Immunother* 2014;**10**:1712–20. doi:10.4161/hv.28621

86 Abadura SA, Lerebo WT, Kulkarni U, *et al.* Individual and community level determinants of childhood full immunization in Ethiopia: a multilevel analysis. *BMC Public Health* 2015;**15**:972. doi:10.1186/s12889-015-2315-z

87 Ebot JO. 'Girl power!': The relationship between women's autonomy and children's immunization coverage in Ethiopia. *J Heal Popul Nutr* 2015;**33**:1–9. doi:10.1186/s41043-015-0028-7

88 Hajizadeh M, Heymann J, Strumpf E, *et al.* Paid maternity leave and childhood vaccination uptake: Longitudinal evidence from 20 low-and-middle-income countries. *Soc Sci Med* 2015;**140**:104–17. doi:10.1016/j.socscimed.2015.07.008

89 Lakew Y, Bekele A, Biadgilign S. Factors influencing full immunization coverage among 12–23 months of age children in Ethiopia: evidence from the national demographic and health survey in 2011. *BMC Public Health* 2015;**15**:728. doi:10.1186/s12889-015-2078-6

90 McGlynn N, Wilk P, Luginaah I, *et al.* Increased use of recommended maternal health care as a determinant of immunization and appropriate care for fever and diarrhoea in Ghana: An analysis pooling three demographic and health surveys. *Health Policy Plan* 2015;**30**:895–905. doi:10.1093/heapol/czu090

91 Mukungwa T. Factors associated with full immunization coverage amongst children aged 12 ???23 months in Zimbabwe. *Etude la Popul Africaine* 2015;**29**:1761–74.

92 Onsomu EO, Abuya B a, Okech IN, *et al.* Maternal Education and Immunization Status Among Children in Kenya. *Matern Child Health J* 2015;**19**:1724–33. doi:10.1007/s10995-015-1686-1

93 Osetinsky B, Gaydos LM, Leon JS. Predictors of completed childhood vaccination in Bolivia. *Int J Child Adolesc health* 2015;**8**:413–23.

94 Prusty RK, Keshri K. Differentials in child nutrition and immunization among migrants and non-migrants in Urban India. *Int J Migr Heal Soc Care* 2015;**11**:194–205. doi:10.1108/IJMHSC-02-2014-0006

95 Rossi R. Do maternal living arrangements influence the vaccination status of children age 12-23 months? A data analysis of demographic health surveys 2010-11 from Zimbabwe. *PLoS One* 2015;**10**:1–19. doi:10.1371/journal.pone.0132357

96 Schweitzer A, Krause G, Pessler F, *et al.* Improved coverage and timing of childhood vaccinations in two post-Soviet countries, Armenia and Kyrgyzstan. *BMC Public Health*

2015;**15**:798. doi:10.1186/s12889-015-2091-9

97 Shrivastwa N, Gillespie BW, Kolenic GE, *et al.* Predictors of Vaccination in India for Children Aged 12-36 Months. *Am J Prev Med* 2015;**49**:S435-44. doi:10.1016/j.amepre.2015.05.008

98 Singh K, Bloom S, Brodish P. Gender Equality as a Means to Improve Maternal and Child Health in Africa. *Heal Care Women Int* 2015;**36**:57–69. doi:doi:10.1080/07399332.2013.824971

99 Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res* 2015;**54**:146–58. doi:10.1016/j.ssresearch.2015.06.005

100 Tsawe M, Moto A, Netshivhera T, *et al.* Factors influencing the use of maternal healthcare services and childhood immunization in Swaziland. *Int J Equity Health* 2015;**14**:32. doi:10.1186/s12939-015-0162-2

101 Arsenault C, Harper S, Nandi A, *et al.* Monitoring equity in vaccination coverage: A systematic analysis of demographic and health surveys from 45 Gavi-supported countries. *Vaccine* 2016;**35**:951–9. doi:10.1016/j.vaccine.2016.12.041

102 Chima CC, Franzini L. Spillover effect of HIV-specific foreign aid on immunization services in Nigeria. *Int Health* 2016;**8**:108–15. doi:10.1093/inthealth/ihv036

103 Gurmu E, Etana D. Factors Influencing Children's Full Immunization in Ethiopia. *African Popul Stud* 2016;**30**:2306–17.

104 Hosseinpoor AR, Bergen N, Schlotheuber A, *et al.* State of inequality in diphtheria-tetanus-pertussis immunisation coverage in low-income and middle-income countries: A multicountry study of household health surveys. *Lancet Glob Heal* 2016;**4**:e617–26. doi:10.1016/S2214-109X(16)30141-3

105 Kriss JL, Goodson J, Machekanyanga Z, *et al.* Vaccine receipt and vaccine card availability among children of the apostolic faith: analysis from the 2010-2011 Zimbabwe demographic and health survey. *Pan Afr Med J* 2016;**24**:47. doi:10.11604/pamj.2016.24.47.8663

106 Kumar C, Singh PK, Singh L, *et al.* Socioeconomic disparities in coverage of full immunisation among children of adolescent mothers in India, 1990–2006: a repeated cross-sectional analysis. *BMJ Open* 2016;**6**:e009768. doi:10.1136/bmjopen-2015-009768

107 Schweitzer A, Pessler F, Akmatov MK. Impact of rotavirus vaccination on coverage and timing of pentavalent vaccination ??? Experience from 2 Latin American countries. *Hum Vaccines Immunother* 2016;**12**:1250–6. doi:10.1080/21645515.2015.1127486

108 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. doi:10.1186/s12889-017-4137-7

109 Aghaji AE. Trends in Measles Vaccination in Nigeria and Implications for Childhood Blindness. *Int J Med Heal Dev* 2017;**22**:82–8. doi:10.4314/jcm.v22i2.4

110 Ambel AA, Andrews C, Bakilana AM, *et al.* Examining changes in maternal and child health inequalities in Ethiopia. *Int J Equity Health* 2017;**16**:152. doi:10.1186/s12939-017-0648-1

111 Delprato M, Akyeampong K. The Effect of Early Marriage Timing on Women's and

Children's Health in Sub-Saharan Africa and Southwest Asia. *Ann Glob Heal* 2017;**83**:557–67. doi:10.1016/j.aogh.2017.10.005

112 Herliana P, Douiri A. Determinants of immunisation coverage of children aged 12-59 months in Indonesia: a cross-sectional study. *BMJ Open* 2017;**7**:e015790. doi:10.1136/bmjopen-2016-015790

113 Kazungu JS, Adetifa IMO. Crude childhood vaccination coverage in West Africa: Trends and predictors of completeness. *Wellcome open Res* 2017;**2**:12. doi:10.12688/wellcomeopenres.10690.1

114 KC A, Nelin V, Raaijmakers H, *et al.* Increased immunization coverage addresses the equity gap in Nepal. *Bull World Health Organ* 2017;**95**:261–9. doi:10.2471/BLT.16.178327

115 Khan MT, Zaheer S, Shafique K. Maternal education, empowerment, economic status and child polio vaccination uptake in Pakistan: a population based cross sectional study. *BMJ Open* 2017;**7**:e013853. doi:10.1136/bmjopen-2016-013853

116 Mbengue MAS, Sarr M, Faye A, *et al.* Determinants of complete immunization among senegalese children aged 12-23 months: evidence from the demographic and health survey. *BMC Public Health* 2017;**17**:630. doi:10.1186/s12889-017-4493-3

117 Oleribe O, Kumar V, Awosika-Olumo A, *et al.* Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. *Pan Afr Med J* 2017;**26**:220. doi:10.11604/pamj.2017.26.220.11453

118 Singh A, Patel SK. Gender differentials in feeding practices, health care utilization and nutritional status of children in Northern India. *Int J Hum Rights Healthc* Published Online First: 2017. doi:10.1108/IJHRH-05-2017-0023

119 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. doi:10.1080/21645515.2017.1336590

120 Zuhair M, Roy RB. Socioeconomic Determinants of the Utilization of Antenatal Care and Child Vaccination in India. *Asia-Pacific J public Heal* 2017;**29**:649–59. doi:10.1177/1010539517747071

121 Acharya P, Kismul H, Mapatano MA, *et al.* Individual- and community-level determinants of child immunization in the Democratic Republic of Congo: A multilevel analysis. *PLoS One* Published Online First: 2018. doi:10.1371/journal.pone.0202742

122 Adetokunboh OO, Uthman OA, Wiysonge CS. Non-uptake of childhood vaccination among the children of HIV-infected mothers in sub-Saharan Africa: A multilevel analysis. *Hum Vaccin Immunother* 2018;**14**:2405–13. doi:10.1080/21645515.2018.1502524

123 Adetokunboh OO, Uthman OA, Wiysonge CS. Effect of maternal HIV status on vaccination coverage among sub-Saharan African children: A socio-ecological analysis. *Hum Vaccin Immunother* 2018;**14**:2373–81. doi:10.1080/21645515.2018.1467204

124 Ashbaugh HR, Hoff NA, Doshi RH, *et al.* Predictors of measles vaccination coverage among children 6-59 months of age in the Democratic Republic of the Congo. *Vaccine* 2018;**36**:587–93. doi:10.1016/j.vaccine.2017.11.049

125 Asuman D, Ackah CG, Enemark U. Inequalities in child immunization coverage in Ghana: evidence from a decomposition analysis. *Health Econ Rev* 2018;**8**:9. doi:10.1186/s13561-018-0193-7

126 Boulton ML, Carlson BF, Power LE, *et al.* Socioeconomic factors associated with full childhood vaccination in Bangladesh, 2014. *Int J Infect Dis* Published Online First: 2018. doi:10.1016/j.ijid.2018.01.035

127 Burroway R, Hargrove A. Education is the antidote: Individual- and community-level effects of maternal education on child immunizations in Nigeria. *Soc Sci Med* 2018;**213**:63–71. doi:10.1016/j.socscimed.2018.07.036

128 Imran W, Abbas F, Javed SA. What is causing high polio vaccine dropout among Pakistani children? *Public Health* 2018;**164**:16–25. doi:10.1016/j.puhe.2018.07.008

129 Khan J, Shil A, Prakash R. Exploring the spatial heterogeneity in different doses of vaccination coverage in India. *PLoS One* 2018;**13**:e0207209. doi:10.1371/journal.pone.0207209

130 Kols A, Gorar Z, Sharjeel M, *et al.* Provincial differences in levels, trends, and determinants of childhood immunization in Pakistan. *East Mediterr Heal J* 2018;**24**:333–44. doi:10.26719/2018.24.4.333

131 McGavin ZA, Wagner AL, Carlson BF, *et al.* Childhood full and under-vaccination in Nigeria, 2013. *Vaccine* 2018;**36**:7294–9. doi:10.1016/j.vaccine.2018.10.043

132 Raza O, Lodhi FS, Morasae EK, *et al.* Differential achievements in childhood immunization across geographical regions of Pakistan: analysis of wealth-related inequality. *Int J Equity Health* 2018;**17**:122. doi:10.1186/s12939-018-0837-6

133 Shenton LM, Wagner AL, Carlson BF, *et al.* Vaccination status of children aged 1-4 years in Afghanistan and associated factors, 2015. *Vaccine* 2018;**36**:5141–9. doi:10.1016/j.vaccine.2018.07.020

134 Shenton LM, Wagner AL, Bettampadi D, *et al.* Factors Associated with Vaccination Status of Children Aged 12–48 Months in India, 2012–2013. *Matern Child Health J* 2018;**22**:1–10. doi:10.1007/s10995-017-2409-6

135 Sohn M, Lin L, Jung M. Effects of Maternal Decisional Authority and Media Use on Vaccination for Children in Asian Countries. *Medicina (Kaunas)* 2018;**54**. doi:10.3390/medicina54060105

136 Lungu EA, Biesma R, Chirwa M, *et al.* Is the Urban Child Health Advantage Declining in Malawi?: Evidence from Demographic and Health Surveys and Multiple Indicator Cluster Surveys. *J Urban Health* 2019;**96**:131–43. doi:10.1007/s11524-018-0270-6

137 Masters NB, Wagner AL, Carlson BF, *et al.* Childhood vaccination in Kenya: socioeconomic determinants and disparities among the Somali ethnic community. *Int J Public Health* 2019;**64**:313–22. doi:10.1007/s00038-018-1187-2

138 Vyas P, Kim D, Adams A. Understanding Spatial and Contextual Factors Influencing Intraregional Differences in Child Vaccination Coverage in Bangladesh. *Asia-Pacific J public Heal* 2019;**31**:51–60. doi:10.1177/1010539518813604

139 Centers for Disease Control and Prevention. Achievements in public health: elimination of rubella and congenital rubella syndrome-US, 1969-2004. *MMWR Morb Mortal Wkly Rep* 2005;**54**:279–82.

140 Mwenge W, Mbulu LK, Okeibunor J, *et al.* Polio Eradication Initiative: Contribution to improved communicable diseases surveillance in WHO African region. *Vaccine* 2016;**34**:5170–4. doi:10.1016/j.vaccine.2016.05.060

141 Keegan R, Dabbagh A, Strebel PM, *et al.* Comparing measles with previous eradication programs: enabling and constraining factors. *J Infect Dis* 2011;**204**:S54–61. doi:10.1093/infdis/jir119

142 Levin A, Burgess C, Garrison LP, *et al.* Global Eradication of Measles: An Epidemiologic and Economic Evaluation. *J Infect Dis* 2011;**204**:S98–106. doi:10.1093/infdis/jir096

143 Thapa A, Khanal S, Sharapov U, *et al.* Progress Toward Measles Elimination - South-East Asia Region, 2003-2013. *MMWR Morb Mortal Wkly Rep* 2015;**64**:613–7.

144 Tsega A, Daniel F, Steinglass R. Monitoring coverage of fully immunized children. *Vaccine* 2014;**32**:7047–9. doi:10.1016/j.vaccine.2014.10.057

145 Hong R, Banta JE. Effects of extra immunization efforts on routine immunization at district level in Pakistan. *East Mediterr Heal J* 2005;**11**.

146 Krieger N, Smith GD. The tale wagged by the DAG: Broadening the scope of causal inference and explanation for epidemiology. *Int J Epidemiol* 2016;**45**:1787–808. doi:10.1093/ije/dyw114

147 Westreich D, Greenland S. The table 2 fallacy: Presenting and interpreting confounder and modifier coefficients. *Am J Epidemiol* 2013;**177**:292–8. doi:10.1093/aje/kws412

148 Bandoli G, Palmsten K, Chambers CD, *et al.* Revisiting the Table 2 fallacy: A motivating example examining preeclampsia and preterm birth. *Paediatr Perinat Epidemiol* 2018;**32**:390–7. doi:10.1111/ppe.12474

149 Bolton P, Hussain A, Hadpawat A, *et al.* Deficiencies in current childhood immunization indicators. *Public Heal Rep* 1998;**113**:527–32.

150 Laubereau B, Hermann M, Schmitt HJ, *et al.* Detection of delayed vaccinations: a new approach to visualize vaccine uptake. *Epidemiol Infect* 2002;**128**:185–92.

151 Shrivastwa N, Gillespie BW, Lepkowski JM, *et al.* Vaccination Timeliness in Children under India's Universal Immunization Program. *Pediatr Infect Dis J* 2016;**35**:955–60. doi:10.1097/INF.0000000000001223

152 Dandona R, Pandey A, Dandona L. A review of national health surveys in India. *Bull World Heal Organ* 2016;**94**:286–96. doi:10.2471/BLT.15.158493

153 UNICEF. Multiple Indicator Cluster Surveys. 2017.http://mics.unicef.org/ (accessed 3 Oct 2017).

154 Wagner AL. The use and significance of vaccination cards. *Hum Vaccin Immunother* 2019;**15**:2844–6. doi:10.1080/21645515.2019.1625647

155 Central Statistical Agency, The DHS Program. Ethiopia Demographic and Health Survey, 2016. 2016.

Figure legends

Figure 1. Diagram of studies' selection into a scoping review of vaccination studies using the Demographic and Health Surveys.

Figure 2. Map of countries which have had Demographic and Health Survey (DHS) datasets published in vaccination studies using only one country. Countries with a DHS between 2003-2016 without studies are separately indicated.

Figure 3. Commonly reported predictors of vaccination status used in studies using the Demographic and Health Survey.

Table 1. List of papers included in a scoping review of studies assessing vaccination status using the Demographic and Health Survey (DHS).

Author	Year	Countries	Age of Child	Vaccination Outcome	Quality score
Bowie [17]	2006	Malawi	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	4
Choi [18]	2006	India	12-48 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Gaudin [19]	2006	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	3
Akmatov [20]	2007	Kazakhstan	12-60 months	Full (BCG + 4OPV + 3DTP + MCV)	8
Anand [21]	2007	Multicountry	Not specified	OPV, DTP, MCV	3
Bhandari [22]	2007	Nepal	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	5
Datar [23]	2007	India	2-35 months	OPV, Full (BCG + 3OPV + 3DTP + MCV)	5
Minh Thang [24]	2007	Vietnam	11-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Munthali [25]	2007	Malawi	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	3
Ntenda [26]	2007	Malawi	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	6
Chidiebere [27]	2008	Nigeria	0-23 months	Full (BCG + 4OPV + 3Penta + 1 MCV + YF)	7
Gatchell [28]	2008	India	1-3 years	Full (BCG + 3OPV + 3DTP + MCV)	4
Halder [29]	2008	Bangladesh	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Meheus [30]	2008	Multicountry	12-23 months	MCV	4
Patra [31]	2008	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Antai [32]	2009	Nigeria	Older than 12 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Antai [33]	2009	Nigeria	Older than 12 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Bondy [34]	2009	Philippines	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Corsi [35]	2009	India	Under 5 years	BCG, OPV, DTP, MCV, Full (age dependent after 9 months)	3
Osaki [36]	2009	Indonesia	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	3
Sia [37]	2009	Burkina Faso	12-23 months	Full (BCG + 3OPV + 3DTP + MCV + YF)	6
Antai [38]	2010	Nigeria	12 months and older	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	8
Hong [39]	2010	Cambodia	12-59 months	DTP	8
Rahman [40]	2010	Bangladesh	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Sahu [41]	2010	India	Preceding 2 births in last 3 years	Full (BCG + 3OPV + 3DTP + MCV)	5
Semali [42]	2010	Tanzania	12-23 months	Full (BCG + 4OPV + 3DTP + MCV)	6
Abuya [43]	2011	Kenya	12-35 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Antai [44]	2011	Nigeria	12 months and older	Full (BCG + 3OPV + 3DTP + MCV)	6
Fernandez [45]	2011	Indonesia	0-59 months	BCG, OPV, DTP, MCV, HepB	9
Fernandez [46]	2011	Indonesia	0-59 months	MCV	8

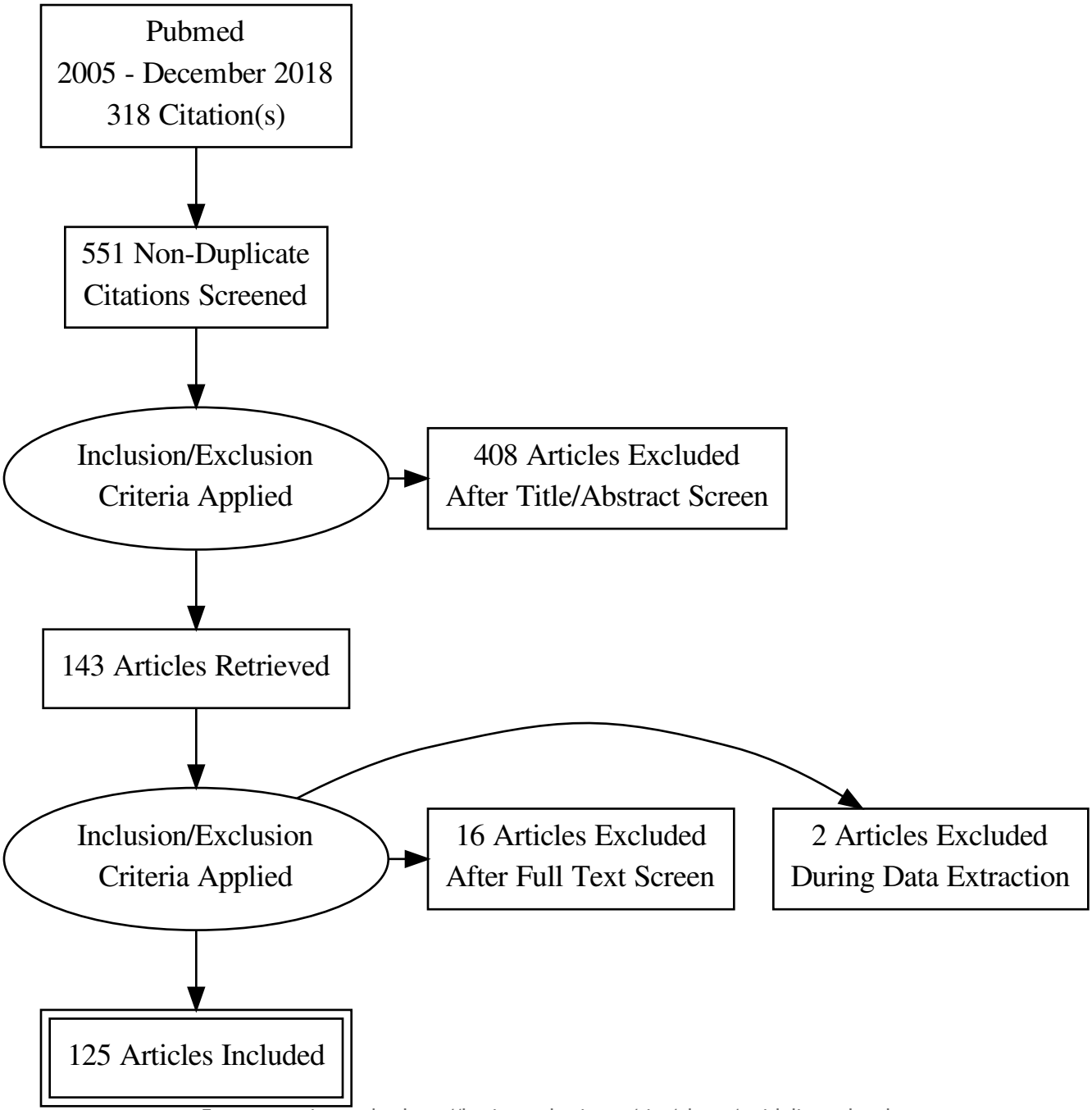
Kumar [47]	2011	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Lauridsen [48]	2011	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Pandey [49]	2011	Nepal	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [50]	2011	India	12-48 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Afzal [51]	2012	Bangladesh	Under 5 years	Full (BCG + 3OPV + 3DTP + MCV)	5
Antai [52]	2012	Nigeria	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Rammohan [53]	2012	Multicountry	Not specified	MCV	5
Sabarwal [54]	2012	India	12-24 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [55]	2012	India	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Wiysonge [56]	2012	Multicountry	12-23 months	Full (DTP3)	6
Barman [57]	2013	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Bbaale [58]	2013	Uganda	0-36 months (12 - 36 for full)	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	8
Haque [59]	2013	Bangladesh	9-59 months	MCV	8
Kumar [60]	2013	India	0-59 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Moyer [61]	2013	Ethiopia	12-24 months	BCG, OPV, DTP, MCV, Full (BCG + 3Penta + 4OPV + 1MCV)	6
Singh [62]	2013	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Singh [63]	2013	Nigeria	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [64]	2013	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Van Malderen [65]	2013	Kenya	12-23 months	MCV	6
Adegboye [66]	2014	Nigeria	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Bonfrer [67]	2014	Burundi	Older than 1 year	BCG, OPV, DTP, MCV	7
Bugvi [68]	2014	Pakistan	12-23 months	Full (BCG + 3DTP + 4OPV + 3HepB + 1MCV)	9
Canavan [69]	2014	Multicountry	12-23 months	Full (BCG + 4OPV + 1 MCV + 3Penta)	9
Clouston [70]	2014	Madagascar	0-59 months	BCG, OPV, DTP, MCV, Hib	7
Ebot [71]	2014	Ethiopia	12-30 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Grundy [72]	2014	Multicountry	Not specified	DTP	3
Heaton [73]	2014	Bolivia	Not specified	Full (BCG + 3OPV + 3DTP + MCV)	4
Helleringer [74]	2014	Multicountry	12-23 months	OPV, SIA participation	4
Javed [75]	2014	Pakistan	12-28 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	8
Luqman [76]	2014	Nigeria	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 4OPV + 3DTP + MCV)	6
Malhotra [77]	2014	India	Older than 12 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Neupane [78]	2014	Nepal	Not specified	Full (BCG + 1DTP + 1OPV)	8
Prusty [79]	2014	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Rai [80]	2014	Niger	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	7

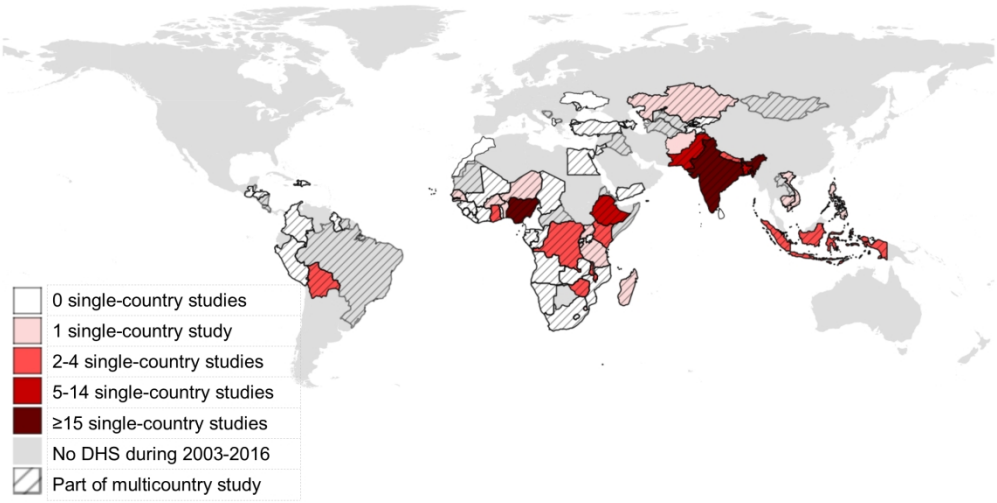
Singh [81]	2014	Multicountry	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Singh [82]	2014	India	12-36 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Ushie [83]	2014	Nigeria	Under 5 years	Full (BCG + 3OPV + 3DTP + MCV)	7
Wagner [84]	2014	Multicountry	0-59 months	BCG	8
Zaidi [85]	2014	Pakistan	0-5 years	OPV, DTP, MCV	9
Abadura [86]	2015	Ethiopia	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Ebot [87]	2015	Ethiopia	12-30 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Hajizadeh [88]	2015	Multicountry	Under 59 months	BCG, OPV, DTP	8
Lakew [89]	2015	Ethiopia	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	8
McGlynn [90]	2015	Ghana	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	9
Mukungwa [91]	2015	Zimbabwe	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Onsomu [92]	2015	Kenya	12-23 months	BCG, OPV, DTP, MCV	8
Osetinsky [93]	2015	Bolivia	24 months - 5 years	Full (BCG + 3 Polio + 3DTP + 1MMR + YF)	6
Prusty [94]	2015	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Rossi [95]	2015	Zimbabwe	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	9
Schweitzer [96]	2015	Multicountry	12-59 months	DTP, MCV	6
Shrivastwa [97]	2015	India	12-36 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [98]	2015	Multicountry	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Smith-Greenaway [99]	2015	Benin	1-59 months	Ever received any vaccine	6
Tsawe [100]	2015	eSwatini	Not specified	Ever received any vaccine	9
Arsenault [101]	2016	Multicountry	12-23 months	DTP, MCV	5
Chima [102]	2016	Nigeria	12-59 months	BCG, OPV, DTP, MCV	6
Gurmu [103]	2016	Ethiopia	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Hosseinpoor [104]	2016	Multicountry	12–23 months in most	DTP	5
Kriss [105]	2016	Zimbabwe	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3Penta + 1MCV	9
Kumar [106]	2016	India	12-23 months	Full (BCG + 3DTP + 3OPV + 1MCV)	9
Restrepo-Méndez [11]	2016	Multicountry	12–23 months in most	Full (BCG + 3DTP + 3OPV + 1MCV)	6
Restrepo-Méndez [12]	2016	Multicountry	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	4
Schweitzer [107]	2016	Multicountry	Birth - 250 weeks	DTP	5
Adedokun [108]	2017	Nigeria	12-23 months	Full (BCG + 3OPV + 3Penta + MCV)	7
Aghaji [109]	2017	Nigeria	12-23 months	MCV	4

Ambel [110]	2017	Ethiopia	12-23 months	MCV, Full (BCG + 3DTP + 3OPV + 1MCV	4
Arsenault [10]	2017	Multicountry	12-23 months	DTP, MCV	8
Delprato [111]	2017	Multicountry	Not specified	Full (BCG + DTP + OPV + MCV (no. unspecified))	5
Herliana [112]	2017	Indonesia	12-59 months	Full (BCG + 3DTP + 4OPV + 1MCV + 1HepB	9
Kazungu [113]	2017	Multicountry	12-23 months	Full (BCG + 3DTP + 3OPV + 1MCV)	7
KC [114]	2017	Nepal	Not specified	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	6
Khan [115]	2017	Pakistan	Under 5 years	OPV	7
Mbengue [116]	2017	Senegal	12-23 months	Full (BCG + 3Penta + 3OPV + 1MCV)	8
Oleribe [117]	2017	Nigeria	12-24 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV dose + 1MCV)	5
Singh [118]	2017	India	12-13 months	Full (Not defined)	6
Uthman [119]	2017	Nigeria	12-23 months	OPV	9
Zuhair [120]	2017	India	Not specified	BCG, OPV, DTP, MCV	7
Acharya [121]	2018	DRC	12-23 months	Full (BCG +3DTP + 3OPV + 1MCV)	9
Adetokunboh [122]	2018	Multicountry	12-23 months	DTP	6
Adetokunboh [123]	2018	Multicountry	12-23 months	DTP	4
Ashbaugh [124]	2018	DRC	6-59 months	MCV	9
Asuman [125]	2018	Ghana	12-59 months	Full (BCG + 3DTP + 3OPV + 1MCV)	8
Boulton [126]	2018	Bangladesh	12-24 months	BCG, OPV, DTP, MCV, Full (BCG + 3Penta + 3OPV + 1MCV)	7
Burroway [127]	2018	Nigeria	12-24 months	Full (BCG + 3DTP + 4OPV + 1MCV)	7
Imran [128]	2018	Pakistan	12-23 months	OPV	7
Khan [129]	2018	India	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3 OPV + 1MCV)	9
Kols [130]	2018	Pakistan	12-23 months	BCG, OPV, DTP, MCV, Full (BCG +3DTP + 3OPV + 1MCV)	9
McGavin [131]	2018	Nigeria	12-24 months	Full (BCG + 3DTP + 4OPV + 1MCV)	9
Raza [132]	2018	Pakistan	12-23 months	Full (BCG +3DTP + 3OPV + 3HepB + 3Hib + 1MCV)	5
Shenton [133]	2018	Afghanistan	12-60 months	Full (BCG +3Penta + 3OPV + 1MCV)	10
Shenton [134]	2018	India	12-48 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Sohn [135]	2018	Multicountry	Not specified	BCG, OPV, DTP, MCV	7
Lungu [136]	2019	Malawi	Not specified	Full (not specified)	1
Masters [137]	2019	Kenya	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3Penta + 3OPV + 1MCV)	10
Vyas [138]	2019	Bangladesh	Not specified	BCG, DTP, MCV	3

Notes:

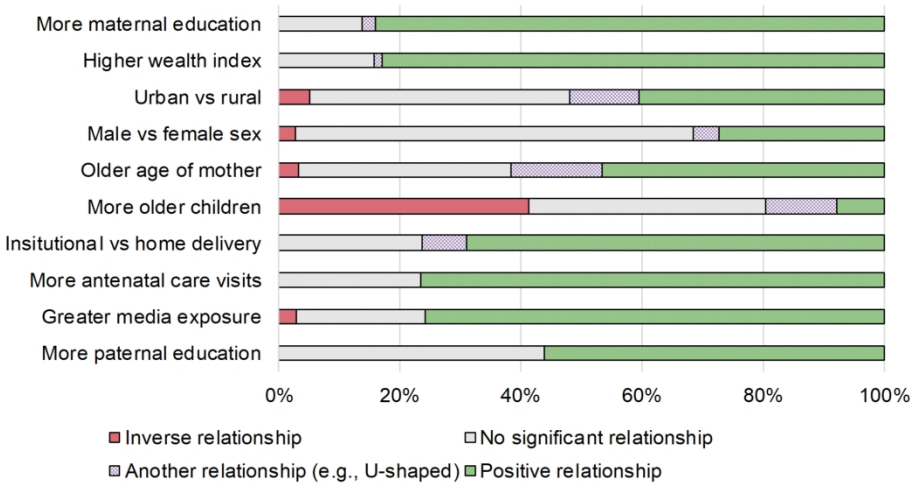
BCG, bacillus Calmette-Guérin; DRC, Democratic Republic of the Congo; DTP, diphtheria –tetanus-pertussis vaccine; HepB, hepatitis B vaccine; Hib, *Haemophilus influenzae* type b vaccine; MCV, measles-containing vaccine; MMR, measles-mumps-rubella vaccine; OPV, oral polio vaccine; Penta, pentavalent vaccine; SIA, supplementary immunization activity; YF, yellow fever


Pubmed
2005 - December 2018
318 Citation(s)
551 Non-Duplicate
Citations Screened
Inclusion/Exclusion
Criteria Applied
408 Articles Excluded
After Title/Abstract Screen
143 Articles Retrieved
Inclusion/Exclusion
Criteria Applied
16 Articles Excluded
After Full Text Screen
2 Articles Excluded
During Data Extraction
125 Articles Included



Map of countries by the number of published studies using Demographic and Health Survey (DHS) datasets. Shading corresponds to number of studies using DHS data from only one country; hash marks indicate a study using multiple countries.

190x101mm (300 x 300 DPI)



Commonly reported predictors of vaccination status used in studies using the Demographic and Health Survey.

190x101mm (300 x 300 DPI)

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-4
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	N/A, 4
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	4
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	4
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	4-5
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	5
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	5

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	6
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	7
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	7-8
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	7
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	7
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	7-8
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	8
Limitations	20	Discuss the limitations of the scoping review process.	10
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	10
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	12

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

BMJ Open

Vaccination Assessments using the Demographic and Health Survey, 2005-2018; A Scoping Review

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-039693.R1
Article Type:	Original research
Date Submitted by the Author:	02-Nov-2020
Complete List of Authors:	Shenton, Luke; University of Michigan, Epidemiology Wagner, Abram; University of Michigan, Epidemiology Ji, Mengdi; University of Michigan, Epidemiology Carlson, Bradley; University of Michigan, Epidemiology Boulton, Matthew; University of Michigan,
Primary Subject Heading:	Global health
Secondary Subject Heading:	Public health
Keywords:	Paediatric infectious disease & immunisation < PAEDIATRICS, Public health < INFECTIOUS DISEASES, International health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Vaccination Assessments using the Demographic and Health Survey, 2005-2018; A Scoping Review

Luke M. Shenton (lshenton@umich.edu) [1,*]
Abram L. Wagner (awag@umich.edu) [1,*,†]
Mengdi Ji (mengdiji@umich.edu) [1]
Bradley F. Carlson (bcarlson@umich.edu) [1]
Matthew L. Boulton (mboulton@umich.edu) [1,2]

[1] Department of Epidemiology, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor, MI 48109, USA

[2] Department of Internal Medicine, Division of Infectious Disease, University of Michigan Medical School, 1500 East Medical Center Drive, Ann Arbor, MI 48109, USA

* Equal contributors

† **Address correspondence to:**
Abram L. Wagner, 1415 Washington Heights, Ann Arbor, MI 48109, USA [awag@umich.edu]
TEL: +001-734-763-2330 FAX: +001-734- 647-1120

Running Head: Scoping review of vaccination assessments

Word Count: 3,608 **Abstract:** 279

ABSTRACT

Objective: To characterize studies which have used DHS datasets to evaluate vaccination status.

Design: Scoping review

Data sources: Electronic databases including PubMed, EBSCOhost, and POPLINE, from 2005-2018

Study selection: All English studies with vaccination status as the outcome and the use of Demographic and Health Survey (DHS) data.

Data extraction: Studies were selected using a predetermined list of eligibility criteria and data was extracted independently by two authors. Data related to the study population, the outcome of interest (vaccination), and commonly seen predictors were extracted.

Results: A total of 125 articles were identified for inclusion in the review. The number of countries covered by individual studies varied widely (1 to 86), with the most published papers using data from India, Nigeria, Pakistan, and Ethiopia. Many different definitions of full vaccination were utilized although the majority used a traditional schedule recommended in the WHO's Expanded Program on Immunization. We found studies analyzed a wide variety of predictors, but the most common were maternal education, wealth, urbanicity, and child's sex. Most commonly reported predictors had consistent relationships with the vaccination outcome, outside of sibling composition.

Conclusions: Researchers make frequent use of the DHS dataset to describe vaccination patterns within one or more countries. A clearer idea of past use of DHS can inform the development of more rigorous studies in the future. Researchers should carefully consider whether a variable needs to be included in the multivariable model, or if there are mediating relationships across predictor variables.

Keywords: vaccine-preventable diseases; developing countries; immunization programs; surveys and questionnaires

Strengths and limitations

- The Demographic and Health Surveys (DHS) are some of the most used sources of national-level vaccination data
- Most DHS studies find consistent relationships between sociodemographic variables and vaccination outcomes.
- There are large variations in how often a country's DHS dataset is used.
- A limitation is the use only of English language material.
- Studies using other national-level vaccination surveys were not included.

INTRODUCTION

Vaccinations have been a cost-effective method to control and achieve elimination and eradication of common and sometimes deadly infectious diseases [1]. The introduction of routine vaccinations in the United States, for example, has led to a >90% decline in cases of diphtheria, measles, mumps, pertussis, polio, rubella, smallpox, and tetanus since the prevaccine era [2]. Nevertheless, every year, more than 2.7 million individuals die from acute illnesses caused by common vaccine-preventable diseases [3]. The overwhelming majority of vaccine-preventable deaths among children <5 years occur in low- and middle-income countries [4].

Based on the prevalence and severity of disease and on the availability of a safe and effective vaccine, the World Health Organization (WHO) recommends that countries include nine vaccines on their publicly funded vaccine schedule for young children [5]. Referred to as the Expanded Program on Immunization (**EPI**), the schedule initially recommended vaccination with Bacillus Calmette-Guérin (BCG), diphtheria-tetanus-pertussis vaccine (DTP), polio vaccine, and a measles-containing vaccine (MCV). Since 2004, five additional pediatric vaccines have been added to the WHO EPI: hepatitis B vaccine (HepB), *Haemophilus influenzae* type b vaccine (Hib), rubella vaccine, pneumococcal conjugate vaccine (PCV), and rotavirus vaccine. Individual countries decide which vaccines to publicly fund and also to make available on the private market resulting in wide variation globally in the adoption of these vaccines. For example, in 2015, 194 countries included 3 doses of DTP and polio in their immunization schedule whereas only 84 included rotavirus [6]. Many countries now use a pentavalent vaccine, which includes DTP, HepB, and Hib vaccines in one vial. Substantial efforts on the part of Gavi The Vaccine Alliance and other international agencies are devoted to logistically and financially supporting the introduction of new and underused vaccines [7]. These efforts are particularly important because a discouragingly high number of children consistently do not receive some or all of the vaccines that were first recommended by the WHO. According to the WHO, 19.4 million children have not received three doses of DTP, with a majority (11.7 million) living in just 10 countries: Nigeria, India, Pakistan, Indonesia, Ethiopia, Philippines, the Democratic Republic of the Congo, Brazil, Angola, and Vietnam [8]. With the exception of Brazil, all of these countries have vaccination coverage regularly assessed as part of the Demographic and Health Survey (DHS) program.

Nationally representative surveys, like those of the DHS program, have been essential to evaluating country- and region-specific vaccination programs over time. DHS programs are funded and facilitated by the US Agency for International Development (USAID). The DHS program was launched in 1984 with a goal of advancing global understanding of health and population trends in developing countries. Since its inception it has provided technical assistance for over 300 surveys in 93 developing countries across the globe. Today, the program is known for collecting and disseminating accurate, nationally representative data on a variety of topics including fertility, family planning, maternal and child health, gender, HIV/AIDS, malaria, and nutrition. Host countries have ownership of data collection, analysis, presentation,

and use and the data is designed to ultimately be used in policy formation, program planning, and monitoring and evaluation [9].

A large number of prior studies have amalgamated data from several different DHS datasets, or have included data from many countries, but none has systematically evaluated how these past studies have actually used the vaccination data provided by DHS [10–12]. Given that DHS has had widespread use over several decades in evaluating vaccination programs through identification of under-vaccinated groups, and characterizing systematic barriers to vaccination, a clearer idea of past use of DHS can inform the development of more rigorous studies in the future. The purpose of this scoping review was to characterize studies which have used DHS datasets to evaluate childhood vaccination status. Specifically we report on the global distribution of studies, list the predictors used in multivariable regression models, and examine the different definitions of "full vaccination" across studies and how these relate to the WHO EPI recommendations.

METHODS

This scoping review was completed by following the steps outlined by the Preferred Reporting Items of Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) [13].

Search Strategies

Searches were performed in 3 different electronic databases: PubMed/MEDLINE, PopLine, and EBSCOhost's Africa-Wide Information, Global Health, Global Health Archives, and Health Policy Reference Center databases. The search terms used were; "Vaccine" (and its variations such as vaccination and vaccinate), "Immunization" (and its variations such as immunize), "demographic and health surveys", "demographic and health survey", "DHS", "National Family Health Survey", and "NFHS". Within PubMed the exact search was the following:

("demographic and health surveys" OR "demographic and health survey" OR "DHS" OR "National Family Health Survey" OR "NFHS") AND (immuniz* OR Vaccin*) AND ("2000/01/01"[PDAT] : "3000/12/31"[PDAT])

In addition, the searches were limited to only return papers published between 1 January 2005 and 31 December 2018. References from articles found to be relevant were searched in order to identify additional articles.

Eligibility Criteria

The titles of all papers returned through use of the search terms were initially screened for relevance. The abstracts of all remaining papers were then accessed with specific inclusion and exclusion criteria in mind. Abstracts and manuscripts were included if they met all inclusion criteria: (1) studies were conducted using DHS data from low or middle-income countries; (2) studies looked at routine vaccination coverage as the primary outcome; (3) studies were cross-

sectional in design; (4) studies used either the Demographic and Health Survey (DHS) or the National Family Health Survey (NFHS), a similar study conducted only in India; (5) studies looked specifically at the vaccination outcome of children (usually aged between 0 and 60 months). A set of exclusion criteria was also created: (1) studies published before 2005 or after 2018 (though studies with an online publication in 2018 but print publication in 2019 were included); (2) studies that looked only at the vaccination outcome of adults; (3) studies that looked at population in high income countries; (4) studies that used modeling or projections instead of just analyzing the data provided; or (5) systematic reviews.

Study Selection

LS removed all duplicates and assessed all titles for relevance. Then three reviewers (LS/BC/AW) independently assessed all abstracts and full-text publications for eligibility using the eligibility criteria laid out. All disagreements were resolved by discussion between reviewers.

Data extraction

In addition to assessment for relevance, data was also extracted independently by three reviewers (LS/BC/AW). A data extraction form was designed using Google Sheets and was piloted before beginning data extraction. Data from 3 main categories was gathered during data extraction. The first area was the study population, including the countries of interest, the subpopulation of children being examined, years of the survey administration, and whether any surveys besides DHS or NFHS were used. The second category was the outcome of interests: which individual vaccines were assessed, whether full or under vaccination was examined, and if full or under vaccination was examined how were they defined. Lastly, data on vaccination predictors was gathered. We tabulated whether a given study included the most common predictors found in a previous systematic review of vaccination timeliness [14]: maternal education, wealth index, urbanicity, sex of child, age of mother, birth order, birth delivery location, number of antenatal care (ANC) visits, media exposure, and paternal education.

Study Methodological quality evaluation

We modified the Downs and Black checklist [15] for assessing biases in systematic reviews because all eligible studies used a similar data source. The checklist included the following criteria:

Introduction / Study population

A. Is the hypothesis/aim/objective of the study clearly described? (1=Yes, 0=No)
B. Are the main outcomes (including defining full vaccination, if applicable) to be measured clearly described in the introduction or methods? (1=Yes, 0=No)
C. Are the characteristics of study population eligibility criteria (including age range) clearly described? (1=Yes, 0=No)

Descriptive Statistics

D. Does the paper use weighting and clustering? (1=Yes, 0=No)

E. Does the paper provide estimates of random variability (e.g., 95% confidence interval of weighted estimates or standard errors) for the main outcomes? (1=Yes, 0=No)

Analytical Statistics

F. Does the paper use do a multivariable analysis? (1=Yes, 0=No)
G. Does the paper show distribution of confounders / covariates? (1=Yes, 0=No)
H. Does the paper describe how the researchers arrived at the final list of confounders? (2=*a priori* knowledge or used directed acyclic graph (DAG), 1=used P-values from crude analysis or used stepwise technique, 0=did not describe or did not use multivariable analysis)
I. Does the paper write out P-values under 0.05? (1= Yes, or provided 95% confidence intervals, 0=No)

The quality score could range from 0-10, and we describe the average values with a mean and median quality score among all studies.

Synthesis of study findings

Given the heterogeneity of outcomes, predictors, and study populations of the included studies it was not possible to combine the results into a meta-analysis. Instead, we present a narrative summary of the data. We describe the distribution of studies by population, what predictor variables are used (and what direction of association they have with outcome), and how full vaccination is defined. In the discussion, we provide recommendations for future analyses of DHS data.

A choropleth map was created using freely available shapefiles from Natural Earth [16] in QGIS 3.6 (QGIS Development Team). The map shows how many studies using data from only one country were published by country. We also show if a country's data was part of a multicountry study, and we identify countries which had a standard DHS dataset administered between 2003 and 2016 but which did not have a published study. The years 2003-2016 were chosen as a lag time of 2 years compared to the scoping review inclusion criteria to account for delays in publishing the data and writing up a manuscript.

Patient and public involvement

This research was done without public involvement. Members of the public were not invited to comment on the study design and were not consulted, nor were they invited to contribute to this document to improve accessibility.

Table 1. List of papers included in a scoping review of studies assessing vaccination status using the Demographic and Health Survey (DHS).

Author	Year	Countries	Age of Child	Vaccination Outcome	Quality score
Bowie [17]	2006	Malawi	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	4
Choi [18]	2006	India	12-48 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Gaudin [19]	2006	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	3
Akmatov [20]	2007	Kazakhstan	12-60 months	Full (BCG + 4OPV + 3DTP + MCV)	8
Anand [21]	2007	Multicountry	Not specified	OPV, DTP, MCV	3
Bhandari [22]	2007	Nepal	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	5
Datar [23]	2007	India	2-35 months	OPV, Full (BCG + 3OPV + 3DTP + MCV)	5
Minh Thang [24]	2007	Vietnam	11-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Munthali [25]	2007	Malawi	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	3
Ntenda [26]	2007	Malawi	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	6
Chidiebere [27]	2008	Nigeria	0-23 months	Full (BCG + 4OPV + 3Penta + 1 MCV + YF)	7
Gatchell [28]	2008	India	1-3 years	Full (BCG + 3OPV + 3DTP + MCV)	4
Halder [29]	2008	Bangladesh	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Meheus [30]	2008	Multicountry	12-23 months	MCV	4
Patra [31]	2008	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Antai [32]	2009	Nigeria	Older than 12 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Antai [33]	2009	Nigeria	Older than 12 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Bondy [34]	2009	Philippines	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Corsi [35]	2009	India	Under 5 years	BCG, OPV, DTP, MCV, Full (age dependent after 9 months)	3
Osaki [36]	2009	Indonesia	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	3
Sia [37]	2009	Burkina Faso	12-23 months	Full (BCG + 3OPV + 3DTP + MCV + YF)	6
Antai [38]	2010	Nigeria	12 months and older	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	8
Hong [39]	2010	Cambodia	12-59 months	DTP	8
Rahman [40]	2010	Bangladesh	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Sahu [41]	2010	India	Preceding 2 births in last 3 years	Full (BCG + 3OPV + 3DTP + MCV)	5
Semali [42]	2010	Tanzania	12-23 months	Full (BCG + 4OPV + 3DTP + MCV)	6
Abuya [43]	2011	Kenya	12-35 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Antai [44]	2011	Nigeria	12 months and older	Full (BCG + 3OPV + 3DTP + MCV)	6
Fernandez [45]	2011	Indonesia	0-59 months	BCG, OPV, DTP, MCV, HepB	9
Fernandez [46]	2011	Indonesia	0-59 months	MCV	8

Kumar [47]	2011	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Lauridsen [48]	2011	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Pandey [49]	2011	Nepal	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [50]	2011	India	12-48 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Afzal [51]	2012	Bangladesh	Under 5 years	Full (BCG + 3OPV + 3DTP + MCV)	5
Antai [52]	2012	Nigeria	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Rammohan [53]	2012	Multicountry	Not specified	MCV	5
Sabarwal [54]	2012	India	12-24 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [55]	2012	India	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Wiysonge [56]	2012	Multicountry	12-23 months	Full (DTP3)	6
Barman [57]	2013	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Bbaale [58]	2013	Uganda	0-36 months (12 - 36 for full)	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	8
Haque [59]	2013	Bangladesh	9-59 months	MCV	8
Kumar [60]	2013	India	0-59 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Moyer [61]	2013	Ethiopia	12-24 months	BCG, OPV, DTP, MCV, Full (BCG + 3Penta + 4OPV + 1MCV)	6
Singh [62]	2013	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Singh [63]	2013	Nigeria	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [64]	2013	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Van Malderen [65]	2013	Kenya	12-23 months	MCV	6
Adegboye [66]	2014	Nigeria	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Bonfrer [67]	2014	Burundi	Older than 1 year	BCG, OPV, DTP, MCV	7
Bugvi [68]	2014	Pakistan	12-23 months	Full (BCG + 3DTP + 4OPV + 3HepB + 1MCV)	9
Canavan [69]	2014	Multicountry	12-23 months	Full (BCG + 4OPV + 1 MCV + 3Penta)	9
Clouston [70]	2014	Madagascar	0-59 months	BCG, OPV, DTP, MCV, Hib	7
Ebot [71]	2014	Ethiopia	12-30 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Grundy [72]	2014	Multicountry	Not specified	DTP	3
Heaton [73]	2014	Bolivia	Not specified	Full (BCG + 3OPV + 3DTP + MCV)	4
Helleringer [74]	2014	Multicountry	12-23 months	OPV, SIA participation	4
Javed [75]	2014	Pakistan	12-28 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3DTP + MCV)	8
Luqman [76]	2014	Nigeria	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 4OPV + 3DTP + MCV)	6
Malhotra [77]	2014	India	Older than 12 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Neupane [78]	2014	Nepal	Not specified	Full (BCG + 1DTP + 1OPV)	8
Prusty [79]	2014	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Rai [80]	2014	Niger	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	7

Singh [81]	2014	Multicountry	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	5
Singh [82]	2014	India	12-36 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Ushie [83]	2014	Nigeria	Under 5 years	Full (BCG + 3OPV + 3DTP + MCV)	7
Wagner [84]	2014	Multicountry	0-59 months	BCG	8
Zaidi [85]	2014	Pakistan	0-5 years	OPV, DTP, MCV	9
Abadura [86]	2015	Ethiopia	12-59 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Ebot [87]	2015	Ethiopia	12-30 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Hajizadeh [88]	2015	Multicountry	Under 59 months	BCG, OPV, DTP	8
Lakew [89]	2015	Ethiopia	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	8
McGlynn [90]	2015	Ghana	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	9
Mukungwa [91]	2015	Zimbabwe	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Onsomu [92]	2015	Kenya	12-23 months	BCG, OPV, DTP, MCV	8
Osetinsky [93]	2015	Bolivia	24 months - 5 years	Full (BCG + 3 Polio + 3DTP + 1MMR + YF)	6
Prusty [94]	2015	India	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Rossi [95]	2015	Zimbabwe	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	9
Schweitzer [96]	2015	Multicountry	12-59 months	DTP, MCV	6
Shrivastwa [97]	2015	India	12-36 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Singh [98]	2015	Multicountry	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	7
Smith-Greenaway [99]	2015	Benin	1-59 months	Ever received any vaccine	6
Tsawe [100]	2015	eSwatini	Not specified	Ever received any vaccine	9
Arsenault [101]	2016	Multicountry	12-23 months	DTP, MCV	5
Chima [102]	2016	Nigeria	12-59 months	BCG, OPV, DTP, MCV	6
Gurmu [103]	2016	Ethiopia	12-23 months	Full (BCG + 3OPV + 3DTP + MCV)	6
Hosseinpoor [104]	2016	Multicountry	12–23 months in most	DTP	5
Kriss [105]	2016	Zimbabwe	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3OPV + 3Penta + 1MCV	9
Kumar [106]	2016	India	12-23 months	Full (BCG + 3DTP + 3OPV + 1MCV)	9
Restrepo-Méndez [11]	2016	Multicountry	12–23 months in most	Full (BCG + 3DTP + 3OPV + 1MCV)	6
Restrepo-Méndez [12]	2016	Multicountry	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	4
Schweitzer [107]	2016	Multicountry	Birth - 250 weeks	DTP	5
Adedokun [108]	2017	Nigeria	12-23 months	Full (BCG + 3OPV + 3Penta + MCV)	7
Aghaji [109]	2017	Nigeria	12-23 months	MCV	4

Ambel [110]	2017	Ethiopia	12-23 months	MCV, Full (BCG + 3DTP + 3OPV + 1MCV	4
Arsenault [10]	2017	Multicountry	12-23 months	DTP, MCV	8
Delprato [111]	2017	Multicountry	Not specified	Full (BCG + DTP + OPV + MCV (no. unspecified))	5
Herliana [112]	2017	Indonesia	12-59 months	Full (BCG + 3DTP + 4OPV + 1MCV + 1HepB	9
Kazungu [113]	2017	Multicountry	12-23 months	Full (BCG + 3DTP + 3OPV + 1MCV)	7
KC [114]	2017	Nepal	Not specified	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	6
Khan [115]	2017	Pakistan	Under 5 years	OPV	7
Mbengue [116]	2017	Senegal	12-23 months	Full (BCG + 3Penta + 3OPV + 1MCV)	8
Oleribe [117]	2017	Nigeria	12-24 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3OPV dose + 1MCV)	5
Singh [118]	2017	India	12-13 months	Full (Not defined)	6
Uthman [119]	2017	Nigeria	12-23 months	OPV	9
Zuhair [120]	2017	India	Not specified	BCG, OPV, DTP, MCV	7
Acharya [121]	2018	DRC	12-23 months	Full (BCG +3DTP + 3OPV + 1MCV)	9
Adetokunboh [122]	2018	Multicountry	12-23 months	DTP	6
Adetokunboh [123]	2018	Multicountry	12-23 months	DTP	4
Ashbaugh [124]	2018	DRC	6-59 months	MCV	9
Asuman [125]	2018	Ghana	12-59 months	Full (BCG + 3DTP + 3OPV + 1MCV)	8
Boulton [126]	2018	Bangladesh	12-24 months	BCG, OPV, DTP, MCV, Full (BCG + 3Penta + 3OPV + 1MCV)	7
Burroway [127]	2018	Nigeria	12-24 months	Full (BCG + 3DTP + 4OPV + 1MCV)	7
Imran [128]	2018	Pakistan	12-23 months	OPV	7
Khan [129]	2018	India	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3DTP + 3 OPV + 1MCV)	9
Kols [130]	2018	Pakistan	12-23 months	BCG, OPV, DTP, MCV, Full (BCG +3DTP + 3OPV + 1MCV)	9
McGavin [131]	2018	Nigeria	12-24 months	Full (BCG + 3DTP + 4OPV + 1MCV)	9
Raza [132]	2018	Pakistan	12-23 months	Full (BCG +3DTP + 3OPV + 3HepB + 3Hib + 1MCV)	5
Shenton [133]	2018	Afghanistan	12-60 months	Full (BCG +3Penta + 3OPV + 1MCV)	10
Shenton [134]	2018	India	12-48 months	Full (BCG + 3OPV + 3DTP + MCV)	8
Sohn [135]	2018	Multicountry	Not specified	BCG, OPV, DTP, MCV	7
Lungu [136]	2019	Malawi	Not specified	Full (not specified)	1
Masters [137]	2019	Kenya	12-23 months	BCG, OPV, DTP, MCV, Full (BCG + 3Penta + 3OPV + 1MCV)	10
Vyas [138]	2019	Bangladesh	Not specified	BCG, DTP, MCV	3

Notes:

BCG, bacillus Calmette-Guérin; DRC, Democratic Republic of the Congo; DTP, diphtheria –tetanus-pertussis vaccine; HepB, hepatitis B vaccine; Hib, *Haemophilus influenzae* type b vaccine; MCV, measles-containing vaccine; MMR, measles-mumps-rubella vaccine; OPV, oral polio vaccine; Penta, pentavalent vaccine; SIA, supplementary immunization activity; YF, yellow fever

RESULTS

Our search terms initially yielded 938 papers; 318 from PubMed, 323 from EBSCOhost, and 211 from POPLINE. An additional 86 papers were identified through searching the references of selected papers. After removing duplicates, 551 papers remained. These papers' abstracts were screened using the inclusion and exclusion criteria to narrow down the study pool to 143 papers. However, during full text screen and data extraction another 18 studies were removed, which left 125 (Figure 1).

The quality sum score (possible range from 0-10) was on average 6.48 with a median of 7. The most commonly missed items contributing to a lower quality sum score were absence of exact P-values or confidence intervals (64% did not), not including estimates of random variability for the outcome (52%), and failure to account for appropriate use of clustering and weights (44%).

DHS has operated in a total of 92 countries since its inception, and between 2003 and 2016, has conducted surveys in 71 different countries.

Overall, 23 (18%) studies used DHS datasets from multiple countries, ranging from 2 countries [81,96,107] to 86 countries [11]. Seven studies used data from multiple African countries [56,69,84,98,113,122,123], 4 from just Asian countries [72,81,96,135], 1 from the Americas [107], and the remainder (11) used data from multiple continents [10,11,111,12,21,30,53,74,88,101,104]. For one study, we were unable to determine what exact countries were included in the analysis [111].

Figure 2 is a choropleth map showing which countries' DHS dataset have been used for vaccination studies. The most frequently represented country is India (26 studies, 21%), followed by Nigeria (17, 14%), Ethiopia and Pakistan (7 each, 6%), and Bangladesh (6, 5%). Notably, there are many countries (44) in the Americas, Europe, and Africa, which had one or more DHS conducted between 2003 and 2016 yet for which there are no corresponding single-country papers published using DHS data in this scoping review. However, most of these countries were a part of multicountry studies. Only five countries' DHS datasets were not part of any (single country or multicountry) DHS study: Cabo Verde, Maldives, Morocco, Sri Lanka, and Ukraine.

Characteristics of the papers are shown in Table 1. About half (51%) of studies included children 12 to 23 or 24 months of age, and the two next most common age ranges were 12 to 59 or 60 months of age (11%) and 0 to 59 months of age (8%).

Full vaccination was assessed in three-fourths (94, 75%) of papers; otherwise, the four most common vaccines assessed one at a time were MCV (39, 31%), DTP (36, 29%), polio (33, 26%), and BCG (27, 22%). There were at least 12 different definitions of full vaccination used in the papers including in this scoping review. Of the 94 papers which evaluated full vaccination coverage, most (66, 70%) used a traditional schedule based off of the four vaccines first

recommended for the WHO's EPI in 1974: 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose MCV. Five (5%) papers modified this traditional definition to include a birth dose of polio, and eleven others used a pentavalent vaccine instead of DTP (of these, 3 had a 4 dose polio schedule, and 8 had a 3-dose polio schedule). Other papers modified the traditional definition in order to include yellow fever (in a total of 4 papers), measles-mumps-rubella vaccine (in one paper), or to exclude certain vaccine series, like measles, polio, or BCG. Some measure of DTP was included in all definitions of full vaccination. No papers included information about PCV or rotavirus vaccine as an outcome in a multivariable regression model, although one used rotavirus vaccine as a predictor variable [107].

Four variables were used in a majority of studies. The top 10 variables used in a study (with their relationship shown in a model) are maternal education (in 94, or 75% of studies), wealth index (88, 70%), urbanicity (79, 63%), child's sex (73, 58%), mother's age (60, 48%), birth order (51, 41%), delivery location (42, 34%), ANC visits (34, 27%), media exposure (33, 26%), and paternal education (32, 26%).

The relationship between the most commonly used predictor and vaccination outcomes is shown in Figure 3. For most predictors there is a relatively clear relationship to vaccination outcome. For a majority of studies, greater vaccination coverage (across any vaccination outcome considered) was related to maternal education (in 84% of studies that considered the variable), higher wealth index (83%), more ANC visits (76%), greater media exposure (76%), an institutional birth (69%), and more paternal education (56%). For several predictors, a large proportion of studies found no significant relationship. This was especially true for child's sex (66% of studies), more paternal education (44%), and urbanicity (43%). Sibling composition was one variable for which there was no clear relationship with the outcome: in 41% of studies, having more older siblings was associated with lower vaccination coverage, in 8% it was associated with higher vaccination coverage, and for the rest of studies, there was no significant relationship (35%) or there was a significant, non-monotonic relationship (12%).

DISCUSSION

Vaccination programs enjoy wide support from many international health organizations and national governments. Vaccination has achieved the sole instance of human disease eradication – smallpox, while polio, measles, and rubella have been eliminated in some regions of the world [1,139]. Global vaccination coverage has increased in recent years but 12.8 million children in 2015 still had not yet received DTP dose 1 [6], a common marker of routine immunization initiation. Regularly conducted studies on vaccination uptake are necessary to assessing population level susceptibility and immunization program reach while also ensuring that countries are on track with international guidelines for maintaining high vaccination coverage and the control or elimination of certain vaccine-preventable diseases. The DHS datasets tend to be very large, both in number of variables looked at and number of participants surveyed. This allows the examination of many possible associations with sufficient statistical power and the ability to control for a number of possible confounders.

DHS is not conducted in all LMICs, only in certain countries with a USAID presence, and it is conducted at irregular intervals. However, it is one of the most widely available surveys for assessing vaccinations globally. This systematic review found wide variation in how full vaccination was defined across 125 studies using DHS data between 2005 and 2018. However, the majority of studies did look at full vaccination and defined it according to the WHO's EPI schedule; 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose MCV. Additionally, studies looked at similar sub-populations (children <5) and very similar predictors, with the most common being maternal education, wealth, urbanicity, and child's sex.

The vaccines commonly evaluated reflect priorities of international efforts. For example, polio was targeted for elimination by 2018 [140]. Measles is also subject to an international elimination effort [141,142], and all 6 WHO regional offices have established target dates for elimination [143]. BCG was one of the first vaccines ideally administered shortly after birth (joined more recently in certain locations with HepB and polio birth doses). And DTP dose 3 has long been used as a proxy for adherence to repeat visits to immunization appointments [144,145]. As more vaccines are added to the vaccine schedule, not only does it become more complicated, but it likely introduces the potential for greater diversity among countries in their respective EPI schedules. Over the past few decades, DHS has operated in 92 countries. However, a significant number of papers came from a relatively small number of countries. We note the most commonly used countries (India, Nigeria, Ethiopia, Pakistan, and Bangladesh) are among the 12 most populous countries in the world, and, with the exception of Bangladesh, are among the five countries with the most number of unvaccinated children [8]. Given that countries have control over their own vaccine policies and utilize a wide variety of socioeconomic variables across individual countries, more country-specific analyses of DHS vaccination data is important.

Recommendations for future analyses

This study identified the variables commonly used as explanatory variables in multivariable regression models. Many studies appeared to use the DHS datasets to test the significance and estimate the strength of association for many explanatory variables concomitantly. Since DHS is a cross-sectional study it cannot be used to investigate the effect of an exposure which could vary across time, such as education or urbanicity. However, a strength of DHS is its ability to be used as a hypothesis generating device. Associations can subsequently be examined in other types of studies, such as cohort studies.

However, given consistent relationships between commonly used predictors and outcomes, it is worth revisiting the use of DHS datasets in multivariable analyses. First, given this consistency, it is more important than ever to consider the plausible causal relationships across all variables utilized in a model. An approach widely used in epidemiology is to chart the directionality of relationships among variables through directed acyclic graphs (DAGs) [146]. Online software, like dagitty.net, can be used to build these models and assess which variables should be

included in the final multivariable model. A potential problem is inclusion of so many variables in one model can obscure the mediating effects of certain variables [147]. For example, researchers examining the relationship between media exposure and vaccination status may include maternal age as a confounder. However, the parameter estimate for maternal age in this multivariable model includes the mediator media exposure. Theoretically, a model with age as the main predictor and with media exposure as a main predictor would have different sets of covariates. Although the potential impact of inappropriately controlling for mediation is context-specific, one study suggests parameter estimates may change up to 10%-25% [148].

Evolving immunization schedules mean that future studies will likely take local programmatic considerations into account. However, to make cross country comparisons, studies could still provide an estimate of full vaccination using the traditional BCG, 3 dose polio, 3 dose DTP, and 1 dose MCV schedule.

Timeliness has also emerged as an important dimension of vaccination uptake within the past two decades [149,150]. Measures of timeliness require vaccination dates [14], information missing from many individuals in the DHS datasets. For example, in the 2006-2007 Pakistan DHS EPI immunization cards, and thus data on vaccination dates, were available for just 10% of cases [85].

Finally, researchers analyzing DHS data should be aware of its structure and limitations. Most DHS samples are stratified and based on clusters. Studies should use survey procedures and weights to ensure that estimates are representative of the national population and that standard errors are honest reflections of the sampling structure. Additionally, because DHS includes so many individuals with unknown vaccination age, any study should account for this substantial left censoring, through Turnbull estimation methods [151] or accelerated failure time models. A substantial minority of studies examined did not specify the age range of the study population. This has implications for timeliness but should be presented in studies calculating more traditional measures of vaccine uptake that do not incorporate timing or age.

The DHS provides national estimates from politically neutral sources over time, in countries where USAID operates. Its continued existence ensures that reliable, comparable, and nationally representative data sources are publicly available. Other surveys, like the District Level Household Survey (DLHS) and the Annual Health Survey (AHS) in India and the Multiple Indicators Cluster Survey (MICS) in over 100 countries, are developed in close collaboration with DHS [152,153].

Limitations

There are several limitations to this study. Because the study populations, use of explanatory variables, and definitions of outcomes differed among studies, we were unable to conduct a meta-analysis to compare the association of various explanatory variables on outcomes. We did not examine the grey literature or non-English language papers as part of this review, nor did

we review reports which may have listed vaccination coverage, but did not include some statistical analysis. Inclusion of these types of articles could have included data from more countries. Vaccination data from the DHS is limited in that it partially comes from information contained on vaccination cards [154], and partially from parental recall – with its obvious potential for errors. However, some countries, such as Ethiopia, have attempted to combat this problem in recent years through the introduction of a Health Facility Questionnaire. This questionnaire is used to record vaccination information for all children, who were discovered to not have a vaccination card during administration of the Woman's Questionnaire [155]. In addition, since the DHS is a standardized questionnaire there is limited opportunity to modify the survey to be locally relevant and take predictors into account that may only be relevant in parts of the country. However, overall the DHS programs are widely available surveys providing researchers, policymakers, and the public with nationally representative data. These data provide a basis for evaluation of immunization programs that would either not exist or not be as robust in their absence.

Conclusions

This scoping review of papers about vaccination published using DHS data found diversity in analyses and qualities of studies. Although certain countries – like India, Nigeria, Pakistan, and Ethiopia – have had ≥7 vaccination studies published using DHS data, there are dozens of countries whose vaccination data have not yet been published within single-country studies. Studies find consistent relationships between greater vaccination uptake and more maternal education, higher wealth index, more ANC visits, greater media exposure, and institutional delivery. The relationship between birth order and vaccination status is more varied across countries. Researchers using the DHS datasets should understand the limitations of using recorded vaccination dates, and should clarify the interpretation of estimates from multivariable analyses given the potential for mediation.

Acknowledgements

We are grateful to the DHS personnel who diligently carry out their work and to USAID for sponsoring the DHS projects.

Funding

ALW's salary was supported by the National Institute Of Allergy And Infectious Diseases of the National Institutes of Health under Award Number K01AI137123. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Competing Interests

The authors declare no competing interests.

Author contributions

MLB conceived of the study design, helped interpret the data, and revised the manuscript critically for important intellectual content. LMS and BFC downloaded manuscripts, assessed their fit for this systematic review, abstracted data from the manuscripts, completed qualitative synthesis, and helped revise the manuscript critically for important intellectual content. MJ abstracted data from the manuscripts and helped revise the manuscript critically for important intellectual content. ALW helped interpret the data, and drafted the article. All authors gave final approval of the manuscript to be published.

Data sharing statement

The data abstracted from these studies are publicly available: https://doi.org/10.6084/m9.figshare.12177135

REFERENCES

1 Centers for Disease Control and Prevention. Ten great public health achievements, 1900–1999: impact of vaccines universally recommended for children. *Morb Mortal Wkly Rep* 1999;**48**:243–8.

2 Roush SW, Murphy T V. Historical comparisons of morbidity and mortality for vaccine-preventable diseases in the United States. *JAMA* 2007;**298**:2155–63. doi:10.1001/jama.298.18.2155

3 Lozano R, Naghavi M, Foreman K, *et al.* Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**:2095–128. doi:10.1016/S0140-6736(12)61728-0

4 Black RE, Cousens S, Johnson HL, *et al.* Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet (London, England)* 2010;**375**:1969–87. doi:10.1016/S0140-6736(10)60549-1

5 World Health Organization. Summary of WHO Position Papers - Recommendations for Routine Immunization. 2017.http://www.who.int/immunization/policy/Immunization_routine_table1.pdf (accessed 7 Sep 2017).

6 Casey RM, Dumolard L, Danovaro-Holliday MC, *et al.* Global Routine Vaccination Coverage, 2015. *Morb Mortal Wkly Rep* 2016;**65**:1270–3.

7 GAVI Alliance. Vaccine goal indicators. GAVI. 2015.http://www.gavi.org/results/goal-level-indicators/vaccine-goal-indicators/ (accessed 2 Jun 2016).

8 Peck M, Gacic-Dobo M, Diallo MS, *et al.* Global routine vaccination coverage, 2018. *Morb Mortal Wkly Rep* 2019;**68**:937–42. doi:10.15585/mmwr.mm6645a3

9 The DHS Program. The DHS Program: Demographic and Health Surveys. 2017.https://dhsprogram.com/ (accessed 3 Oct 2017).

10 Arsenault C, Johri M, Nandi A, *et al.* Country-level predictors of vaccination coverage and inequalities in Gavi-supported countries. *Vaccine* 2017;**35**:2479–88. doi:10.1016/j.vaccine.2017.03.029

11 Restrepo-Méndez MC, Barros AJD, Wong KLM, *et al.* Inequalities in full immunization coverage : trends in low- and middle-income countries. *Bull World Heal Organ* 2016;**94**:794–805. doi:10.2471/BLT.15.162172

12 Restrepo-Méndez MC, Barros AJD, Wong KLM, *et al.* Missed opportunities in full immunization coverage: Findings from low- and lower-middle-income countries. *Glob Health Action* 2016;**9**:1–6. doi:10.3402/gha.v9.30963

13 Moher D, Liberati A, Tetzlaff J, *et al.* Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009;**151**:264–9, W64.

14 Masters NB, Wagner AL, Boulton ML. Vaccination timeliness in low- and middle-income countries: a systematic review of the literature, 2007-2017. *Hum Vaccin Immunother* 2019;**15**:2790–805. doi:10.1080/21645515.2019.1616503

15 Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Heal* 1998;**52**:377–84.

16 Natural Earth. Admin 0 - Countries. 2020.https://www.naturalearthdata.com/downloads/50m-cultural-vectors/50m-admin-0-countries-2/ (accessed 30 Mar 2020).
17 Bowie C, Mathanga D, Misiri H. Poverty, access and immunization in Malawi - a descriptive study. Malawi Med. J. 2006;**18**:19–27. doi:10.4314/mmj.v18i1.10902
18 Choi JY, Lee S-H. Does prenatal care increase access to child immunization? Gender bias among children in India. *Soc Sci Med* 2006;**63**:107–17. doi:10.1016/j.socscimed.2005.11.063
19 Gaudin S, Yazbeck AS. Immunization in india 1993-1999: Wealth, gender, and regional inequalities revisited. *Soc Sci Med* 2006;**62**:694–706. doi:10.1016/j.socscimed.2005.06.042
20 Akmatov MK, Kretzschmar M, Krämer A, *et al.* Determinants of childhood vaccination coverage in Kazakhstan in a period of societal change: Implications for vaccination policies. *Vaccine* 2007;**25**:1756–63. doi:10.1016/j.vaccine.2006.11.030
21 Anand S, Bärnighausen T. Health workers and vaccination coverage in developing countries: an econometric analysis. *Lancet* 2007;**369**:1277–85. doi:10.1016/S0140-6736(07)60599-6
22 Bhandari P, Shrestha SS, Ghimire DJ. Sociocultural and geographical disparities in child immunization in Nepal. *Asia-Pacific Popul J* 2007;**22**:43–64.
23 Datar A, Mukherji A, Sood N. Health infrastructure & immunization coverage in rural India. *Indian J Med Res* 2007;**125**:31–42.
24 Minh Thang N, Bhushan I, Bloom E, *et al.* Child immunization in Vietnam: situation and barriers to coverage. *J Biosoc Sci* 2007;**39**:41–58. doi:10.1017/S0021932006001234
25 Munthali AC. Determinants of vaccination coverage in Malawi: evidence from the demographic and health surveys. *Malawi Med J* 2007;**19**:79–82. doi:10.4314/mmj.v19i2.10934
26 Ntenda PAM, Chuang K-Y, Tiruneh FN, *et al.* Analysis of the effects of individual and community level factors on childhood immunization in Malawi. *Vaccine* Published Online First: 2017. doi:10.1016/j.vaccine.2017.02.036
27 Chidiebere ODI, Uchenna E, Kenechi OS. Maternal sociodemographic factors that influence full child immunisation uptake in Nigeria. *SAJCH South African J Child Heal* 2014;**8**:138–42. doi:10.7196/SAJCH.661
28 Gatchell M, Thind A, Hagigi F. Informing state-level health policy in India: The case of childhood immunizations in Maharashtra and Bihar. *Acta Paediatr Int J Paediatr* 2008;**97**:124–6. doi:10.1111/j.1651-2227.2007.00569.x
29 Halder AK, Kabir M. Inequalities in infant immunization coverage in Bangladesh. *Heal Serv Insights* 2008;**1**:5–11.
30 Meheus F, Van Doorslaer E. Achieving better measles immunization in developing countries: does higher coverage imply lower inequality? *Soc Sci Med* 2008;**66**:1709–18. doi:10.1016/j.socscimed.2007.12.036
31 Patra N. Exploring the Determinants of Childhood Immunisation. *Econ Polit Wkly* 2008;**43**:97–104.
32 Antai D. Inequitable childhood immunization uptake in Nigeria: a multilevel analysis of individual and contextual determinants. *BMC Infect Dis* 2009;**9**:181. doi:10.1186/1471-2334-9-181

33 Antai D. Faith and Child Survival: the Role of Religion in Childhood Immunization in Nigeria. *J Biosoc Sci* 2009;**41**:57. doi:10.1017/S0021932008002861

34 Bondy JN, Thind A, Koval JJ, *et al.* Identifying the determinants of childhood immunization in the Philippines. *Vaccine* 2009;**27**:169–75. doi:10.1016/j.vaccine.2008.08.042

35 Corsi DJ, Bassani DG, Kumar R, *et al.* Gender inequity and age-appropriate immunization coverage in India from 1992 to 2006. *BMC Int Health Hum Rights* 2009;**9 Suppl 1**:S3. doi:10.1186/1472-698X-9-S1-S3

36 Osaki K, Hattori T, Kosen S, *et al.* Investment in home-based maternal, newborn and child health records improves immunization coverage in Indonesia. *Trans R Soc Trop Med Hyg* 2009;**103**:846–8. doi:10.1016/j.trstmh.2009.03.011

37 Sia D, Fournier P, Kobiané J-F, *et al.* Rates of coverage and determinants of complete vaccination of children in rural areas of Burkina Faso (1998-2003). *BMC Public Health* 2009;**9**:416. doi:10.1186/1471-2458-9-416

38 Antai D. Migration and child immunization in Nigeria: individual- and community-level contexts. *BMC Public Health* 2010;**10**:116. doi:10.1186/1471-2458-10-116

39 Hong R, Chhea V. Trend and inequality in immunization dropout among young children in Cambodia. *Matern Child Health J* 2010;**14**:446–52. doi:10.1007/s10995-009-0466-1

40 Rahman M, Obaida-Nasrin S. Factors affecting acceptance of complete immunization coverage of children under five years in rural Bangladesh. *Salud Publica Mex* 2010;**52**:134–40. doi:10.1590/S0036-36342010000200005

41 Sahu D, Pradhan J, Jayachandran V, *et al.* Why immunization coverage fails to catch up in India? A community-based analysis. *Child Care Health Dev* 2010;**36**:332–9. doi:10.1111/j.1365-2214.2009.01003.x

42 Semali IA. Trends in immunization completion and disparities in the context of health reforms: the case study of Tanzania. *BMC Health Serv Res* 2010;**10**:299. doi:10.1186/1472-6963-10-299

43 Abuya BA, Onsomu EO, Kimani JK, *et al.* Influence of maternal education on child immunization and stunting in Kenya. *Matern Child Health J* 2011;**15**:1389–99. doi:10.1007/s10995-010-0670-z

44 Antai D. Rural-urban inequities in childhood immunisation in Nigeria: The role of community contexts. *African J Prim Heal Care Fam Med* 2011;**3**. doi:10.4102/phcfm.v3i1.238

45 Fernandez RC, Awofeso N, Rammohan A. Determinants of apparent rural-urban differentials in measles vaccination uptake in Indonesia. *Rural Remote Health* 2011;**11**:1–14.

46 Fernandez R, Rammohan A, Awofeso N. Correlates of first dose of measles vaccination delivery and uptake in Indonesia. *Asian Pac J Trop Med* 2011;**4**:140–5. doi:10.1016/S1995-7645(11)60055-2

47 Kumar A, Mohanty SK. Socio-economic differentials in childhood immunization in India, 1992-2006. *J Popul Res* 2011;**28**:301–24.

48 Lauridsen J, Pradhan J, Kruk M, *et al.* Socio-economic inequality of immunization coverage in India. *Health Econ Rev* 2011;**1**:11. doi:10.1186/2191-1991-1-11

49 Pandey S. Determinants of child immunization in Nepal : The role of women ' s empowerment. *Health Educ J* 2011;**71**:642–53. doi:10.1177/0017896911419343

50 Singh A. Inequality of Opportunity in Indian Children: The Case of Immunization and

Nutrition. *Popul Res Policy Rev* 2011;**30**:861–83. doi:10.1007/s11113-011-9214-5

51 Afzal N, Zainab B. Determinants and Status of Vaccination in Bangladesh. *Dhaka Univ J Sci* 2012;**60**:47–51. doi:10.3329/dujs.v60i1.10336

52 Antai D. Gender inequities, relationship power, and childhood immunization uptake in Nigeria: A population-based cross-sectional study. *Int J Infect Dis* 2012;**16**:e136–45. doi:10.1016/j.ijid.2011.11.004

53 Rammohan A, Awofeso N, Fernandez RC. Paternal education status significantly influences infants' measles vaccination uptake, independent of maternal education status. *BMC Public Health* 2012;**12**:336. doi:10.1186/1471-2458-12-336

54 Sabarwal S, McCormick MC, Silverman JG, *et al.* Association between maternal intimate partner violence victimization and childhood immunization in India. *J Trop Pediatr* 2012;**58**:107–13. doi:10.1093/tropej/fmr052

55 Singh A. Gender based within-household inequality in childhood immunization in India: Changes over time and across regions. *PLoS One* 2012;**7**:e33045. doi:10.1371/journal.pone.0035045

56 Wiysonge CS, Uthman OA, Ndumbe PM, *et al.* Individual and contextual factors associated with low childhood immunisation coverage in Sub-Saharan Africa: A multilevel analysis. *PLoS One* 2012;**7**. doi:10.1371/journal.pone.0037905

57 Barman D, Dutta A. Access and barriers to immunization in West Bengal, India: Quality matters. *J Heal Popul Nutr* 2013;**31**:510–22.

58 Bbaale E. Factors influencing childhood immunization in Uganda. *J Heal Popul Nutr* 2013;**31**:118–27. doi:10.3329/jhpn.v31i1.14756

59 Haque SMR, Bari W. Positive Role of Maternal Education on Measles Vaccination Coverage in Bangladesh. *Int J Psychol Behav Sci* 2013;**3**:11–7. doi:10.5923/j.ijpbs.20130301.02

60 Kumar A, Ram F. Influence of Family Structure on Child Health: Evidence From India. *J Biosoc Sci* 2013;**45**:577–99. doi:10.1017/S0021932012000764

61 Moyer CA, Tadesse L, Fisseha S. The relationship between facility delivery and infant immunization in Ethiopia. *Int J Gynecol Obstet* 2013;**123**:217–20. doi:10.1016/j.ijgo.2013.06.030

62 Singh A, Singh A, Mahapatra B. The consequences of unintended pregnancy for maternal and child health in rural India: Evidence from prospective data. *Matern Child Health J* 2013;**17**:493–500. doi:10.1007/s10995-012-1023-x

63 Singh K, Haney E, Olorunsaiye C. Maternal autonomy and attitudes towards gender norms: Associations with childhood immunization in Nigeria. *Matern Child Health J* 2013;**17**:837–41. doi:10.1007/s10995-012-1060-5

64 Singh PK. Trends in Child Immunization across Geographical Regions in India: Focus on Urban-Rural and Gender Differentials. *PLoS One* 2013;**8**. doi:10.1371/journal.pone.0073102

65 Van Malderen C, Ogali I, Khasakhala A, *et al.* Decomposing Kenyan socio-economic inequalities in skilled birth attendance and measles immunization. *Int J Equity Health* 2013;**12**:3. doi:10.1186/1475-9276-12-3

66 Adegboye O, Kotze D, Adegboye O. Multi-Year Trend Analysis of Childhood Immunization Uptake and Coverage in Nigeria. *J Biosoc Sci* 2014;**46**:225–39.

doi:10.1017/S0021932013000254

67 Bonfrer I, Van de Poel E, Van Doorslaer E. The effects of performance incentives on the utilization and quality of maternal and child care in Burundi. *Soc Sci Med* 2014;**123**:96–104. doi:10.1016/j.socscimed.2014.11.004

68 Bugvi AS, Rahat R, Zakar R, *et al.* Factors associated with non-utilization of child immunization in Pakistan: evidence from the Demographic and Health Survey 2006-07. *BMC Public Health* 2014;**14**:232. doi:10.1186/1471-2458-14-232

69 Canavan ME, Sipsma HL, Kassie GM, *et al.* Correlates of complete childhood vaccination in East African countries. *PLoS One* 2014;**9**:1–7. doi:10.1371/journal.pone.0095709

70 Clouston S, Kidman R, Palermo T. Social inequalities in vaccination uptake among children aged 0-59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009. *Vaccine* 2014;**32**:3533–9. doi:10.1016/j.vaccine.2014.04.030

71 Ebot JO. Place Matters : Community Level Effects of Women ' s Autonomy on Ethiopian Children ' s Immunization Status. *Etude la Popul Africaine/African Popul Stud* 2014;**28**:1202–15.

72 Grundy J, Annear P, Chomat AM, *et al.* Improving average health and persisting health inequities - Towards a justice and fairness platform for health policy making in Asia. *Health Policy Plan* 2014;**29**:873–82. doi:10.1093/heapol/czt068

73 Heaton TB, Crookston B, Forste R, *et al.* Inequalities in child health in Bolivia: Has Morales made a difference? *Heal Sociol Rev* 2014;**23**:208–18. doi:10.1080/14461242.2014.11081974

74 Helleringer S, Abdelwahab J, Vandenent M. Polio supplementary immunization activities and equity in access to vaccination: Evidence from the demographic and health surveys. *J Infect Dis* 2014;**210**:S531–9. doi:10.1093/infdis/jiu278

75 Javed SA, Imran W, Haider A, *et al.* Mothers related differentials in childhood immunization uptake in Pakistan. *Res Humanit Soc Sci* 2014;**4**:62–72.

76 Luqman B, Titus Kolawole O. Mothers' health seeking behaviour and socio-economic differentials: A factor analysis of full childhood immunization in South-Western Nigeria. *J Public Heal Epidemiol* 2014;**6**:132–47. doi:10.5897/JPHE2013.0593

77 Malhotra C, Malhotra R, Østbye T, *et al.* Maternal autonomy and child health care utilization in India: Results from the National Family Health Survey. *Asia-Pacific J Public Heal* 2014;**26**:401–13. doi:10.1177/1010539511420418

78 Neupane S, Nwaru BI. Impact of prenatal care utilization on infant care practices in Nepal: A National representative cross-sectional survey. *Eur J Pediatr* 2014;**173**:99–109. doi:10.1007/s00431-013-2136-y

79 Prusty RK, Kumar A. Socioeconomic dynamics of gender disparity in childhood immunization in India, 1992-2006. *PLoS One* 2014;**9**:1992–2006. doi:10.1371/journal.pone.0104598

80 Rai RK, Singh PK, Singh L, *et al.* Individual characteristics and use of maternal and child health services by adolescent mothers in Niger. *Matern Child Health J* 2014;**18**:592–603. doi:10.1007/s10995-013-1276-z

81 Singh PK, Parsuraman S. Sibling composition and child immunization in India and Pakistan, 1990-2007. *World J Pediatr* 2014;**10**:145–50. doi:10.1007/s12519-014-0483-z

82 Singh PK, Parasuraman S, P.K. S, *et al.* 'Looking beyond the male-female dichotomy' - sibling composition and child immunization in India, 1992-2006. *Soc Sci Med* 2014;**107**:145–53. doi:10.1016/j.socscimed.2014.02.017

83 Ushie BA, Fayehun OA, Ugal DB. Trends and patterns of under-5 vaccination in Nigeria, 1990-2008: What manner of progress? *Child Care Health Dev* 2014;**40**:267–74. doi:10.1111/cch.12055

84 Wagner Z, Szilagyi PG, Sood N. Comparative performance of public and private sector delivery of BCG vaccination: Evidence from Sub-Saharan Africa. *Vaccine* 2014;**32**:4522–8. doi:10.1016/j.vaccine.2014.06.020

85 Zaidi SMA, Khowaja S, Dharma VK, *et al.* Coverage, timeliness, and determinants of immunization completion in Pakistan: Evidence from the Demographic and Health Survey (2006-07). *Hum Vaccines Immunother* 2014;**10**:1712–20. doi:10.4161/hv.28621

86 Abadura SA, Lerebo WT, Kulkarni U, *et al.* Individual and community level determinants of childhood full immunization in Ethiopia: a multilevel analysis. *BMC Public Health* 2015;**15**:972. doi:10.1186/s12889-015-2315-z

87 Ebot JO. 'Girl power!': The relationship between women's autonomy and children's immunization coverage in Ethiopia. *J Heal Popul Nutr* 2015;**33**:1–9. doi:10.1186/s41043-015-0028-7

88 Hajizadeh M, Heymann J, Strumpf E, *et al.* Paid maternity leave and childhood vaccination uptake: Longitudinal evidence from 20 low-and-middle-income countries. *Soc Sci Med* 2015;**140**:104–17. doi:10.1016/j.socscimed.2015.07.008

89 Lakew Y, Bekele A, Biadgilign S. Factors influencing full immunization coverage among 12–23 months of age children in Ethiopia: evidence from the national demographic and health survey in 2011. *BMC Public Health* 2015;**15**:728. doi:10.1186/s12889-015-2078-6

90 McGlynn N, Wilk P, Luginaah I, *et al.* Increased use of recommended maternal health care as a determinant of immunization and appropriate care for fever and diarrhoea in Ghana: An analysis pooling three demographic and health surveys. *Health Policy Plan* 2015;**30**:895–905. doi:10.1093/heapol/czu090

91 Mukungwa T. Factors associated with full immunization coverage amongst children aged 12 ???23 months in Zimbabwe. *Etude la Popul Africaine* 2015;**29**:1761–74.

92 Onsomu EO, Abuya B a, Okech IN, *et al.* Maternal Education and Immunization Status Among Children in Kenya. *Matern Child Health J* 2015;**19**:1724–33. doi:10.1007/s10995-015-1686-1

93 Osetinsky B, Gaydos LM, Leon JS. Predictors of completed childhood vaccination in Bolivia. *Int J Child Adolesc health* 2015;**8**:413–23.

94 Prusty RK, Keshri K. Differentials in child nutrition and immunization among migrants and non-migrants in Urban India. *Int J Migr Heal Soc Care* 2015;**11**:194–205. doi:10.1108/IJMHSC-02-2014-0006

95 Rossi R. Do maternal living arrangements influence the vaccination status of children age 12-23 months? A data analysis of demographic health surveys 2010-11 from Zimbabwe. *PLoS One* 2015;**10**:1–19. doi:10.1371/journal.pone.0132357

96 Schweitzer A, Krause G, Pessler F, *et al.* Improved coverage and timing of childhood vaccinations in two post-Soviet countries, Armenia and Kyrgyzstan. *BMC Public Health*

2015;**15**:798. doi:10.1186/s12889-015-2091-9

97 Shrivastwa N, Gillespie BW, Kolenic GE, *et al.* Predictors of Vaccination in India for Children Aged 12-36 Months. *Am J Prev Med* 2015;**49**:S435-44. doi:10.1016/j.amepre.2015.05.008

98 Singh K, Bloom S, Brodish P. Gender Equality as a Means to Improve Maternal and Child Health in Africa. *Heal Care Women Int* 2015;**36**:57–69. doi:doi:10.1080/07399332.2013.824971

99 Smith-Greenaway E, Madhavan S. Maternal migration and child health: An analysis of disruption and adaptation processes in Benin. *Soc Sci Res* 2015;**54**:146–58. doi:10.1016/j.ssresearch.2015.06.005

100 Tsawe M, Moto A, Netshivhera T, *et al.* Factors influencing the use of maternal healthcare services and childhood immunization in Swaziland. *Int J Equity Health* 2015;**14**:32. doi:10.1186/s12939-015-0162-2

101 Arsenault C, Harper S, Nandi A, *et al.* Monitoring equity in vaccination coverage: A systematic analysis of demographic and health surveys from 45 Gavi-supported countries. *Vaccine* 2016;**35**:951–9. doi:10.1016/j.vaccine.2016.12.041

102 Chima CC, Franzini L. Spillover effect of HIV-specific foreign aid on immunization services in Nigeria. *Int Health* 2016;**8**:108–15. doi:10.1093/inthealth/ihv036

103 Gurmu E, Etana D. Factors Influencing Children's Full Immunization in Ethiopia. *African Popul Stud* 2016;**30**:2306–17.

104 Hosseinpoor AR, Bergen N, Schlotheuber A, *et al.* State of inequality in diphtheria-tetanus-pertussis immunisation coverage in low-income and middle-income countries: A multicountry study of household health surveys. *Lancet Glob Heal* 2016;**4**:e617–26. doi:10.1016/S2214-109X(16)30141-3

105 Kriss JL, Goodson J, Machekanyanga Z, *et al.* Vaccine receipt and vaccine card availability among children of the apostolic faith: analysis from the 2010-2011 Zimbabwe demographic and health survey. *Pan Afr Med J* 2016;**24**:47. doi:10.11604/pamj.2016.24.47.8663

106 Kumar C, Singh PK, Singh L, *et al.* Socioeconomic disparities in coverage of full immunisation among children of adolescent mothers in India, 1990–2006: a repeated cross-sectional analysis. *BMJ Open* 2016;**6**:e009768. doi:10.1136/bmjopen-2015-009768

107 Schweitzer A, Pessler F, Akmatov MK. Impact of rotavirus vaccination on coverage and timing of pentavalent vaccination ??? Experience from 2 Latin American countries. *Hum Vaccines Immunother* 2016;**12**:1250–6. doi:10.1080/21645515.2015.1127486

108 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. doi:10.1186/s12889-017-4137-7

109 Aghaji AE. Trends in Measles Vaccination in Nigeria and Implications for Childhood Blindness. *Int J Med Heal Dev* 2017;**22**:82–8. doi:10.4314/jcm.v22i2.4

110 Ambel AA, Andrews C, Bakilana AM, *et al.* Examining changes in maternal and child health inequalities in Ethiopia. *Int J Equity Health* 2017;**16**:152. doi:10.1186/s12939-017-0648-1

111 Delprato M, Akyeampong K. The Effect of Early Marriage Timing on Women's and

Children's Health in Sub-Saharan Africa and Southwest Asia. *Ann Glob Heal* 2017;**83**:557–67. doi:10.1016/j.aogh.2017.10.005

112 Herliana P, Douiri A. Determinants of immunisation coverage of children aged 12-59 months in Indonesia: a cross-sectional study. *BMJ Open* 2017;**7**:e015790. doi:10.1136/bmjopen-2016-015790

113 Kazungu JS, Adetifa IMO. Crude childhood vaccination coverage in West Africa: Trends and predictors of completeness. *Wellcome open Res* 2017;**2**:12. doi:10.12688/wellcomeopenres.10690.1

114 KC A, Nelin V, Raaijmakers H, *et al.* Increased immunization coverage addresses the equity gap in Nepal. *Bull World Health Organ* 2017;**95**:261–9. doi:10.2471/BLT.16.178327

115 Khan MT, Zaheer S, Shafique K. Maternal education, empowerment, economic status and child polio vaccination uptake in Pakistan: a population based cross sectional study. *BMJ Open* 2017;**7**:e013853. doi:10.1136/bmjopen-2016-013853

116 Mbengue MAS, Sarr M, Faye A, *et al.* Determinants of complete immunization among Senegalese children aged 12-23 months: evidence from the demographic and health survey. *BMC Public Health* 2017;**17**:630. doi:10.1186/s12889-017-4493-3

117 Oleribe O, Kumar V, Awosika-Olumo A, *et al.* Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. *Pan Afr Med J* 2017;**26**:220. doi:10.11604/pamj.2017.26.220.11453

118 Singh A, Patel SK. Gender differentials in feeding practices, health care utilization and nutritional status of children in Northern India. *Int J Hum Rights Healthc* Published Online First: 2017. doi:10.1108/IJHRH-05-2017-0023

119 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. doi:10.1080/21645515.2017.1336590

120 Zuhair M, Roy RB. Socioeconomic Determinants of the Utilization of Antenatal Care and Child Vaccination in India. *Asia-Pacific J public Heal* 2017;**29**:649–59. doi:10.1177/1010539517747071

121 Acharya P, Kismul H, Mapatano MA, *et al.* Individual- and community-level determinants of child immunization in the Democratic Republic of Congo: A multilevel analysis. *PLoS One* Published Online First: 2018. doi:10.1371/journal.pone.0202742

122 Adetokunboh OO, Uthman OA, Wiysonge CS. Non-uptake of childhood vaccination among the children of HIV-infected mothers in sub-Saharan Africa: A multilevel analysis. *Hum Vaccin Immunother* 2018;**14**:2405–13. doi:10.1080/21645515.2018.1502524

123 Adetokunboh OO, Uthman OA, Wiysonge CS. Effect of maternal HIV status on vaccination coverage among sub-Saharan African children: A socio-ecological analysis. *Hum Vaccin Immunother* 2018;**14**:2373–81. doi:10.1080/21645515.2018.1467204

124 Ashbaugh HR, Hoff NA, Doshi RH, *et al.* Predictors of measles vaccination coverage among children 6-59 months of age in the Democratic Republic of the Congo. *Vaccine* 2018;**36**:587–93. doi:10.1016/j.vaccine.2017.11.049

125 Asuman D, Ackah CG, Enemark U. Inequalities in child immunization coverage in Ghana: evidence from a decomposition analysis. *Health Econ Rev* 2018;**8**:9. doi:10.1186/s13561-018-0193-7

126 Boulton ML, Carlson BF, Power LE, *et al.* Socioeconomic factors associated with full childhood vaccination in Bangladesh, 2014. *Int J Infect Dis* Published Online First: 2018. doi:10.1016/j.ijid.2018.01.035

127 Burroway R, Hargrove A. Education is the antidote: Individual- and community-level effects of maternal education on child immunizations in Nigeria. *Soc Sci Med* 2018;**213**:63–71. doi:10.1016/j.socscimed.2018.07.036

128 Imran W, Abbas F, Javed SA. What is causing high polio vaccine dropout among Pakistani children? *Public Health* 2018;**164**:16–25. doi:10.1016/j.puhe.2018.07.008

129 Khan J, Shil A, Prakash R. Exploring the spatial heterogeneity in different doses of vaccination coverage in India. *PLoS One* 2018;**13**:e0207209. doi:10.1371/journal.pone.0207209

130 Kols A, Gorar Z, Sharjeel M, *et al.* Provincial differences in levels, trends, and determinants of childhood immunization in Pakistan. *East Mediterr Heal J* 2018;**24**:333–44. doi:10.26719/2018.24.4.333

131 McGavin ZA, Wagner AL, Carlson BF, *et al.* Childhood full and under-vaccination in Nigeria, 2013. *Vaccine* 2018;**36**:7294–9. doi:10.1016/j.vaccine.2018.10.043

132 Raza O, Lodhi FS, Morasae EK, *et al.* Differential achievements in childhood immunization across geographical regions of Pakistan: analysis of wealth-related inequality. *Int J Equity Health* 2018;**17**:122. doi:10.1186/s12939-018-0837-6

133 Shenton LM, Wagner AL, Carlson BF, *et al.* Vaccination status of children aged 1-4 years in Afghanistan and associated factors, 2015. *Vaccine* 2018;**36**:5141–9. doi:10.1016/j.vaccine.2018.07.020

134 Shenton LM, Wagner AL, Bettampadi D, *et al.* Factors Associated with Vaccination Status of Children Aged 12–48 Months in India, 2012–2013. *Matern Child Health J* 2018;**22**:1–10. doi:10.1007/s10995-017-2409-6

135 Sohn M, Lin L, Jung M. Effects of Maternal Decisional Authority and Media Use on Vaccination for Children in Asian Countries. *Medicina (Kaunas)* 2018;**54**. doi:10.3390/medicina54060105

136 Lungu EA, Biesma R, Chirwa M, *et al.* Is the Urban Child Health Advantage Declining in Malawi?: Evidence from Demographic and Health Surveys and Multiple Indicator Cluster Surveys. *J Urban Health* 2019;**96**:131–43. doi:10.1007/s11524-018-0270-6

137 Masters NB, Wagner AL, Carlson BF, *et al.* Childhood vaccination in Kenya: socioeconomic determinants and disparities among the Somali ethnic community. *Int J Public Health* 2019;**64**:313–22. doi:10.1007/s00038-018-1187-2

138 Vyas P, Kim D, Adams A. Understanding Spatial and Contextual Factors Influencing Intraregional Differences in Child Vaccination Coverage in Bangladesh. *Asia-Pacific J public Heal* 2019;**31**:51–60. doi:10.1177/1010539518813604

139 Centers for Disease Control and Prevention. Achievements in public health: elimination of rubella and congenital rubella syndrome-US, 1969-2004. *MMWR Morb Mortal Wkly Rep* 2005;**54**:279–82.

140 Mwenge W, Mbulu LK, Okeibunor J, *et al.* Polio Eradication Initiative: Contribution to improved communicable diseases surveillance in WHO African region. *Vaccine* 2016;**34**:5170–4. doi:10.1016/j.vaccine.2016.05.060

141 Keegan R, Dabbagh A, Strebel PM, *et al.* Comparing measles with previous eradication programs: enabling and constraining factors. *J Infect Dis* 2011;**204**:S54–61. doi:10.1093/infdis/jir119

142 Levin A, Burgess C, Garrison LP, *et al.* Global Eradication of Measles: An Epidemiologic and Economic Evaluation. *J Infect Dis* 2011;**204**:S98–106. doi:10.1093/infdis/jir096

143 Thapa A, Khanal S, Sharapov U, *et al.* Progress Toward Measles Elimination - South-East Asia Region, 2003-2013. *MMWR Morb Mortal Wkly Rep* 2015;**64**:613–7.

144 Tsega A, Daniel F, Steinglass R. Monitoring coverage of fully immunized children. *Vaccine* 2014;**32**:7047–9. doi:10.1016/j.vaccine.2014.10.057

145 Hong R, Banta JE. Effects of extra immunization efforts on routine immunization at district level in Pakistan. *East Mediterr Heal J* 2005;**11**.

146 Krieger N, Smith GD. The tale wagged by the DAG: Broadening the scope of causal inference and explanation for epidemiology. *Int J Epidemiol* 2016;**45**:1787–808. doi:10.1093/ije/dyw114

147 Westreich D, Greenland S. The table 2 fallacy: Presenting and interpreting confounder and modifier coefficients. *Am J Epidemiol* 2013;**177**:292–8. doi:10.1093/aje/kws412

148 Bandoli G, Palmsten K, Chambers CD, *et al.* Revisiting the Table 2 fallacy: A motivating example examining preeclampsia and preterm birth. *Paediatr Perinat Epidemiol* 2018;**32**:390–7. doi:10.1111/ppe.12474

149 Bolton P, Hussain A, Hadpawat A, *et al.* Deficiencies in current childhood immunization indicators. *Public Heal Rep* 1998;**113**:527–32.

150 Laubereau B, Hermann M, Schmitt HJ, *et al.* Detection of delayed vaccinations: a new approach to visualize vaccine uptake. *Epidemiol Infect* 2002;**128**:185–92.

151 Shrivastwa N, Gillespie BW, Lepkowski JM, *et al.* Vaccination Timeliness in Children under India's Universal Immunization Program. *Pediatr Infect Dis J* 2016;**35**:955–60. doi:10.1097/INF.0000000000001223

152 Dandona R, Pandey A, Dandona L. A review of national health surveys in India. *Bull World Heal Organ* 2016;**94**:286–96. doi:10.2471/BLT.15.158493

153 UNICEF. Multiple Indicator Cluster Surveys. 2017.http://mics.unicef.org/ (accessed 3 Oct 2017).

154 Wagner AL. The use and significance of vaccination cards. *Hum Vaccin Immunother* 2019;**15**:2844–6. doi:10.1080/21645515.2019.1625647

155 Central Statistical Agency, The DHS Program. Ethiopia Demographic and Health Survey, 2016. 2016.

Figure legends

Figure 1. Diagram of studies' selection into a scoping review of vaccination studies using the Demographic and Health Surveys.

Figure 2. Map of countries by the number of published studies using Demographic and Health Survey (DHS) datasets. Shading corresponds to number of studies using DHS data from only one country; hash marks indicate a study using multiple countries.

Figure 3. Commonly reported predictors of vaccination status used in studies using the Demographic and Health Survey.

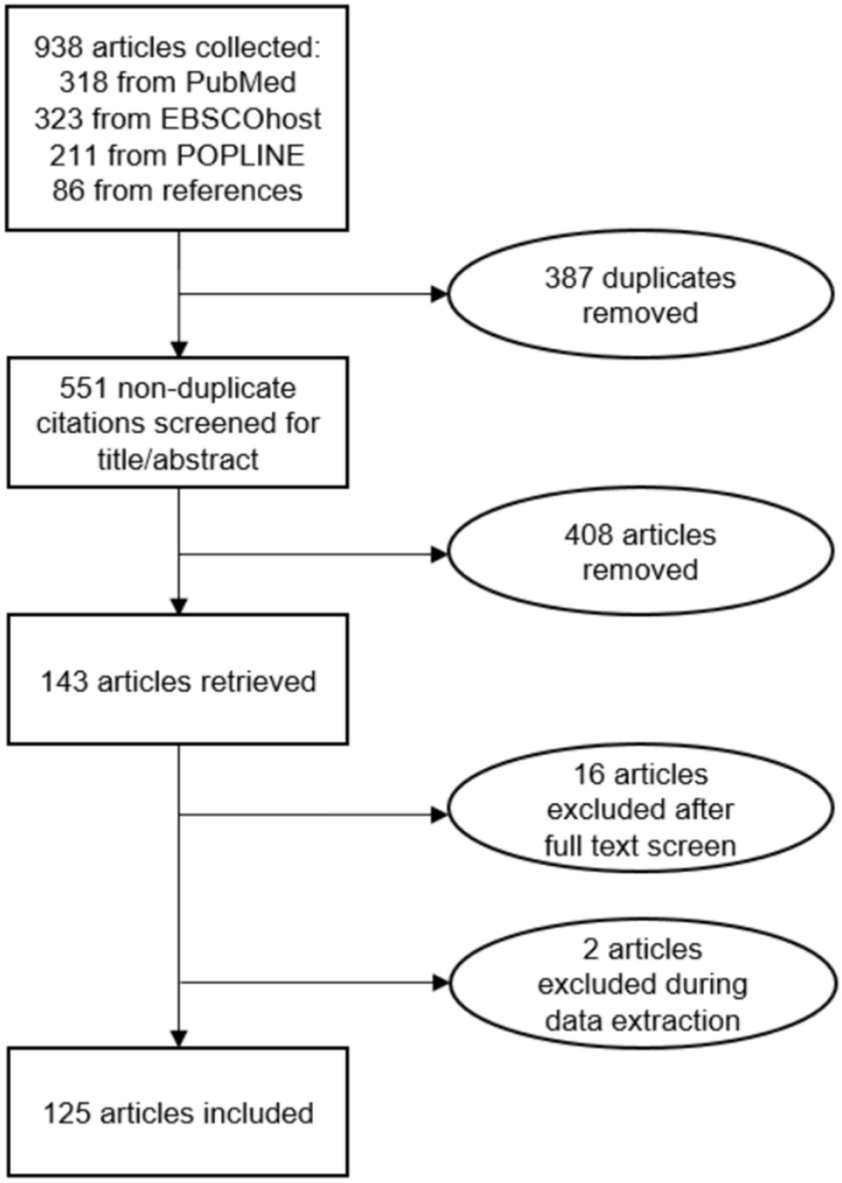
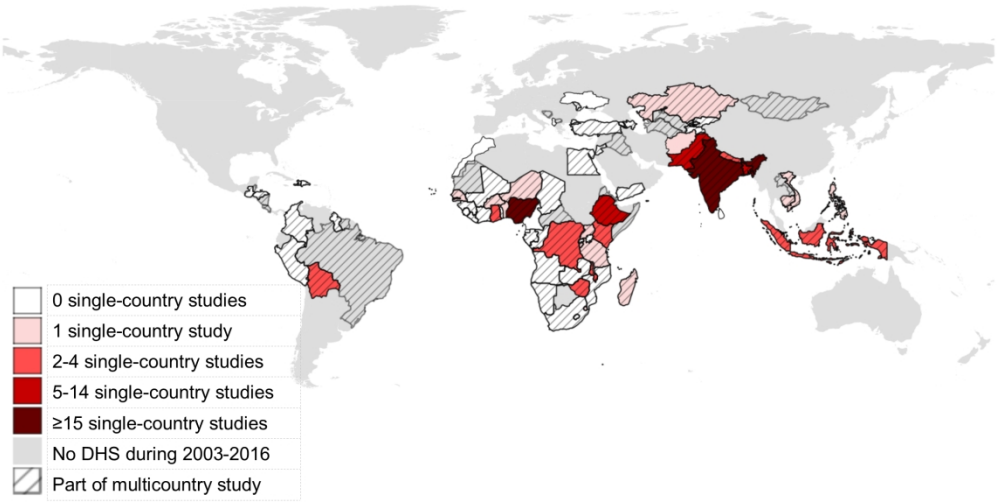


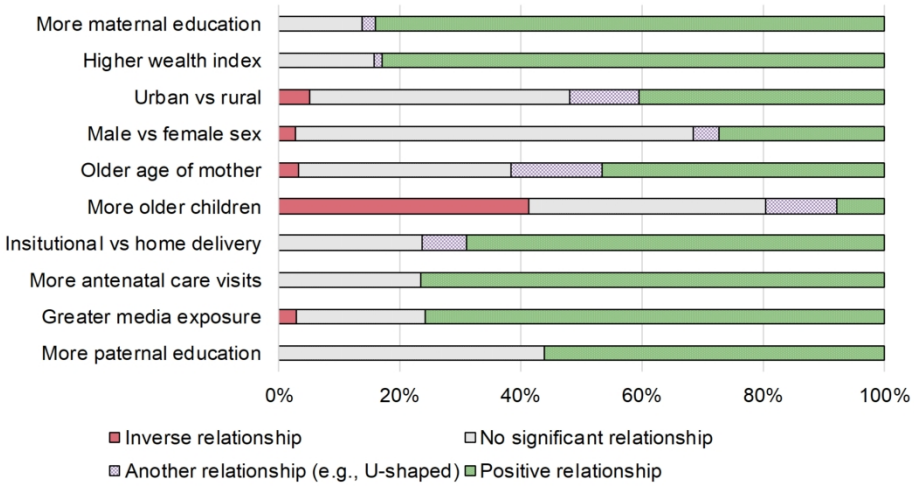
Diagram of studies' selection into a scoping review of vaccination studies using the Demographic and Health Surveys.

114x152mm (300 x 300 DPI)



Map of countries by the number of published studies using Demographic and Health Survey (DHS) datasets. Shading corresponds to number of studies using DHS data from only one country; hash marks indicate a study using multiple countries.

190x101mm (300 x 300 DPI)



Commonly reported predictors of vaccination status used in studies using the Demographic and Health Survey.

190x101mm (300 x 300 DPI)

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-4
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	N/A, 4
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	4
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	4
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	4-5
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	5
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	5

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	6
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	7
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	7-8
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	7
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	7
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	7-8
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	8
Limitations	20	Discuss the limitations of the scoping review process.	10
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	10
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	12

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.