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

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

3
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24 **Running Head:** Scoping review of vaccination assessments

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

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3 32 **ABSTRACT**
4 33

5
6 34 **Objective:** To characterize studies which have used DHS datasets to evaluate vaccination
7 35 status.
8 36

9 37 **Design:** Scoping review
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12 39 **Data sources:** Electronic databases including PubMed, EBSCOhost, and POPLINE, from 2005-
13 40 2018
14 41

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16 42 **Study selection:** All English studies with vaccination status as the outcome and the use of
17 43 Demographic and Health Survey (DHS) data.
18 44

19 45 **Data extraction:** Studies were selected using a predetermined list of eligibility criteria and data
20 46 was extracted independently by two authors. Data related to the study population, the outcome
21 47 of interest (vaccination), and commonly seen predictors were extracted.
22 48

23
24 49 **Results:** A total of 125 articles were identified for inclusion in the review. The number of
25 50 countries covered by individual studies varied widely (1 to 86), with the most published papers
26 51 using data from India, Nigeria, Pakistan, and Ethiopia. Many different definitions of full
27 52 vaccination were utilized although the majority used a traditional schedule recommended in
28 53 the WHO's Expanded Program on Immunization. We found studies analyzed a wide variety of
29 54 predictors, but the most common were maternal education, wealth, urbanicity, and child's sex.
30 55 Most commonly reported predictors had consistent relationships with the vaccination outcome,
31 56 outside of sibling composition.
32 57

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34 58 **Conclusions:** Researchers make frequent use of the DHS dataset to describe vaccination
35 59 patterns within one or more countries. A clearer idea of past use of DHS can inform the
36 60 development of more rigorous studies in the future. Researchers should carefully consider
37 61 whether a variable needs to be included in the multivariable model, or if there are mediating
38 62 relationships across predictor variables.
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41 64 **Keywords:** vaccine-preventable diseases; developing countries; immunization programs;
42 65 surveys and questionnaires
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3 73 **Strengths and limitations**

- 4 74 - The Demographic and Health Surveys (DHS) are some of the most used sources of
5 national-level vaccination data
6 75
7 76 - Most DHS studies find consistent relationships between sociodemographic variables
8 and vaccination outcomes.
9 77
10 78 - There are large variations in how often a country's DHS dataset is used.
11 79 - A limitation is the use only of English language material.
12 80 - Other national-level vaccination surveys are also used.
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82 INTRODUCTION

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84 Vaccinations have been a cost-effective method to control and achieve elimination and
85 eradication of common and sometimes deadly infectious diseases [1]. The introduction of
86 routine vaccinations in the United States, for example, has led to a >90% decline in cases of
87 diphtheria, measles, mumps, pertussis, polio, rubella, smallpox, and tetanus since the
88 prevaccine era [2]. Nevertheless, every year, more than 2.7 million individuals die from acute
89 diseases caused by common vaccine-preventable diseases [3]. The overwhelming majority of
90 vaccine-preventable deaths among children <5 years occur in low- and middle-income countries
91 [4].

92
93 Based on the prevalence and severity of disease and on the availability of a safe and effective
94 vaccine, the World Health Organization (WHO) recommends that countries include nine
95 vaccines on their publicly funded vaccine schedule for young children [5]. Referred to as the
96 Expanded Program on Immunization (EPI), the schedule initially recommended vaccination
97 with Bacillus Calmette-Guérin (BCG), diphtheria-tetanus-pertussis vaccine (DTP), polio vaccine,
98 and a measles-containing vaccine (MCV). Since 2004, five additional pediatric vaccines have
99 been added to the WHO EPI: hepatitis B vaccine (HepB), *Haemophilus influenzae* type b vaccine
100 (Hib), rubella vaccine, pneumococcal conjugate vaccine (PCV), and rotavirus vaccine.
101 Individual countries decide which vaccines to publicly fund and also to make available on the
102 private market resulting in wide variation globally in the adoption of these vaccines. For
103 example, in 2015, 194 countries included 3 doses of DTP and polio in their immunization
104 schedule whereas only 84 included rotavirus [6]. Many countries now use a pentavalent
105 vaccine, which includes DTP, HepB, and Hib vaccines in one vial. Substantial efforts on the part
106 of the GAVI Alliance and other international agencies are devoted to logistically and financially
107 supporting the introduction of new and underused vaccines [7]. These efforts are particularly
108 important because a discouragingly high number of children consistently do not receive some
109 or all of the vaccines that were first recommended by the WHO. According to the WHO, 19.4
110 million children have not received three doses of DTP, with a majority (11.7 million) living in
111 just 10 countries: Nigeria, India, Pakistan, Indonesia, Ethiopia, Philippines, the Democratic
112 Republic of the Congo, Brazil, Angola, and Vietnam [8]. With the exception of Brazil, all of these
113 countries have vaccination coverage regularly assessed as part of the Demographic and Health
114 Survey (DHS) program.

115
116 Nationally representative surveys, like those of the DHS program, have been essential to
117 evaluating country- and region-specific vaccination program over time. DHS programs are
118 funded and facilitated by the US Agency for International Development (USAID). The DHS
119 program was launched in 1984 with a goal of advancing global understanding of health and
120 population trends in developing countries. Since its inception it has provided technical
121 assistance for over 300 surveys in 93 developing countries across the globe. Today, the program
122 is known for collecting and disseminating accurate, nationally representative data on a variety
123 of topics including fertility, family planning, maternal and child health, gender, HIV/AIDS,
124 malaria, and nutrition. Host countries have ownership of data collection, analysis, presentation,

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3 125 and use and the data is designed to ultimately be used in policy formation, program planning,
4 126 and monitoring and evaluation [9].
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6 127

7 128 A large number of prior studies have amalgamated data from several different DHS datasets, or
8 129 have included data from many countries, but none has systematically evaluated how these past
9 130 studies have actually used the vaccination data provided by DHS [10–12]. Given that DHS has
10 131 had widespread use over several decades in evaluating vaccination programs through
11 132 identification of under-vaccinated groups, and characterizing systematic barriers to vaccination,
12 133 a clearer idea of past use of DHS can inform the development of more rigorous studies in the
13 134 future. The purpose of this scoping review was to characterize studies which have used DHS
14 135 datasets to evaluate vaccination status. Specifically we look at the global and temporal
15 136 distribution of studies, list the predictors used in multivariable regression models, and examine
16 137 the different definitions of “full vaccination” and how these relate to the WHO EPI
17 138 recommendations
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19 139

20 140 **METHODS**

21 141

22 142 This scoping review was completed by following the steps outlined by the Preferred Reporting
23 143 Items of Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR)
24 144 [13].
25
26 145

27 146 **Search Strategies**

28 147 Searches were performed in 3 different electronic databases: PubMed/MEDLINE, PopLine, and
29 148 EBSCOhost’s Africa-Wide Information, Global Health, Global Health Archives, and Health
30 149 Policy Reference Center databases. The search terms used were; “Vaccine” (and its variations
31 150 such as vaccination and vaccinate), “Immunization” (and its variations such as immunize),
32 151 “demographic and health surveys”, “demographic and health survey”, “DHS”, “National
33 152 Family Health Survey”, and “NFHS”. In addition, the searches were limited to only return
34 153 papers published between 1 January 2005 and 31 December 2018. References from articles
35 154 found to be relevant were searched in order to identify additional articles.
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37 155

38 156 **Eligibility Criteria**

39 157 The titles of all papers returned through use of the search terms were initially screened for
40 158 relevance. The abstracts of all remaining papers were then accessed with specific inclusion and
41 159 exclusion criteria in mind. Abstracts and manuscripts were included if they met all inclusion
42 160 criteria: (1) studies were conducted using DHS data from low or middle-income countries; (2)
43 161 studies looked at routine vaccination coverage as the primary outcome; (3) studies were cross-
44 162 sectional in design; (4) studies used either the Demographic and Health Survey (DHS) or the
45 163 National Family Health Survey (NFHS), a similar study conducted only in India; (5) studies
46 164 looked specifically at the vaccination outcome of children (usually aged between 0 and 60
47 165 months). A set of exclusion criteria was also created: (1) studies published before 2005 or after
48 166 2018 (though studies with an online publication in 2018 but print publication in 2019 were
49 167 included); (2) studies that looked only at the vaccination outcome of adults; (3) studies that
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3 168 looked at population in high income countries; (4) studies that used modeling or projections
4 169 instead of just analyzing the data provided; or (5) systematic reviews.
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6 170

171 **Study Selection**

8 172 LS removed all duplicate and assessed all titles for relevance. Then three reviewers (LS/BC/AW)
9 173 independently assessed all abstracts and full-text publications for eligibility using the eligibility
10 174 criteria laid out. All disagreements were resolved by discussion between reviewers.
11 175

13 176 **Data extraction**

14 177 In addition to assessment for relevance, data was also extracted independently by three
15 178 reviewers (LS/BC/AW). A data extraction form was designed using Google Sheets and was
16 179 piloted before beginning data extraction. Data from 3 main categories was gathered during data
17 180 extraction. The first area was the study population, including the countries of interest, the
18 181 subpopulation of children being examined, years of the survey administration, and whether any
19 182 surveys besides DHS or NFHS were used. The second category was the outcome of interests:
20 183 which individual vaccines were assessed, whether full or under vaccination was examined, and
21 184 if full or under vaccination was examined how were they defined. Lastly, data on vaccination
22 185 predictors was gathered. We tabulated whether a given study included the most common
23 186 predictors found in a previous systematic review of vaccination timeliness [14]: maternal
24 187 education, wealth index, urbanicity, sex of child, age of mother, birth order, birth delivery
25 188 location, number of antenatal care (ANC) visits, media exposure, and paternal education.
26 189

30 190 **Study Methodological quality evaluation**

31 191 We modified the Downs and Black checklist [15] for assessing biases in systematic reviews
32 192 because all eligible studies used a similar data source. The checklist included the following
33 193 criteria:
34 194

36 195 **Introduction / Study population**

- 37 196 A. Is the hypothesis/aim/objective of the study clearly described? (1=Yes, 0=No)
38 197 B. Are the main outcomes (including defining full vaccination, if applicable) to be
39 198 measured clearly described in the introduction or methods? (1=Yes, 0=No)
40 199 C. Are the characteristics of study population eligibility criteria (including age range)
41 200 clearly described? (1=Yes, 0=No)

44 201 **Descriptive Statistics**

- 45 202 D. Does the paper use weighting and clustering? (1=Yes, 0=No)
46 203 E. Does the paper provide estimates of random variability (e.g., 95% confidence interval of
47 204 weighted estimates or standard errors) for the main outcomes? (1=Yes, 0=No)

49 205 **Analytical Statistics**

- 50 206 F. Does the paper use do a multivariable analysis? (1=Yes, 0=No)
51 207 G. Does the paper show distribution of confounders / covariates? (1=Yes, 0=No)
52 208 H. Does the paper describe how the researchers arrived at the final list of confounders? (2=*a*
53 209 *priori* knowledge or used DAG, 1=used P-values from crude analysis or used stepwise
54 210 technique, 0=did not describe or did not use multivariable analysis)
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3 211 I. Does the paper write out P-values under 0.05? (1= Yes, or provided 95% confidence
4 212 intervals, 0=No)
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7 214 The quality score could range from 0-10.
8 215

9 216 **Synthesis of study findings**

10 217 Given the heterogeneity of outcomes, predictors, and study populations of the included studies
11 218 it was not possible to combine the results into a meta-analysis. Instead, we present a narrative
12 219 summary of the data. We describe the distribution of studies by population, what predictor
13 220 variables are used (and what direction of association they have with outcome), and how full
14 221 vaccination is defined. In the discussion, we provide recommendations for future analyses of
15 222 DHS data.
16 223

17 224 A choropleth map was created using freely available shapefiles from Natural Earth [16] in QGIS
18 225 3.6 (QGIS Development Team). The map shows how many studies using data from only one
19 226 country were published by country. We also show if a country's data was part of a multicountry
20 227 study, and we identify countries which had a standard DHS dataset administered between 2003
21 228 and 2016 but which did not have a published study. The years 2003-2016 were chosen as a lag
22 229 time of 2 years compared to the scoping review inclusion criteria to account for delays in
23 230 publishing the data and writing up a manuscript.
24 231

25 232 **Patient and public involvement**

26 233 This research was done without public involvement. Members of the public were not invited to
27 234 comment on the study design and were not consulted, nor were they invited to contribute to
28 235 this document to improve accessibility.
29 236

30 237 **RESULTS**

31 238
32 239 Our search terms initially yielded 938 papers; 318 from PubMed, 323 from EBSCOhost, and 211
33 240 from POPLINE. An additional 86 papers were identified through searching the references of
34 241 selected papers. After removing duplicates, 551 papers remained. These papers' abstracts were
35 242 screened using the inclusion and exclusion criteria to narrow down the study pool to 143
36 243 papers. However, during full text screen and data extraction another 18 studies were removed,
37 244 which left 125 (Figure 1).
38 245

39 246 The quality sum score (possible range from 0-10) was on average 6.48 with a median of 7. The
40 247 most commonly missed items contributing to a lower quality sum score were absence of exact
41 248 P-values or confidence intervals (64% did not), not including estimates of random variability for
42 249 the outcome (52%), and failure to account for appropriate use of clustering and weights (44%).
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44 251 DHS has operated in a total of 92 countries since its inception, and between 2003 and 2016, has
45 252 conducted surveys in 71 different countries.
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3 254 Overall, 23 studies used DHS datasets from multiple countries, ranging from 2 countries
4 255 [81,96,107] to 86 countries [11]. Seven studies used data from multiple African countries
5 256 [56,69,84,98,113,122,123], 4 from just Asian countries [72,81,96,135], 1 from the Americas [107],
6 257 and the remainder (11) used data from multiple continents [10,11,111,12,21,30,53,74,88,101,104].
7 258 For one study, we were unable to determine what exact countries were included in the analysis
8 259 [111].
9 260

10 261 Figure 2 is a choropleth map showing which countries' DHS dataset have been used for
11 262 vaccination studies. The most frequently represented country is India (26 studies, 21%),
12 263 followed by Nigeria (17, 14%), Ethiopia and Pakistan (7 each, 6%), and Bangladesh (6, 5%).
13 264 Notably, there are many countries (44) in the Americas, Europe, and Africa, which had one or
14 265 more DHS conducted between 2003 and 2016 yet for which there are no corresponding single-
15 266 country papers published using DHS data in this scoping review. However, most of these
16 267 countries were a part of multicountry studies. Only five countries' DHS datasets were not part
17 268 of any (single country or multicountry) DHS study: Cabo Verde, Maldives, Morocco, Sri Lanka,
18 269 and Ukraine.
19 270

20 271 Characteristics of the papers are shown in Table 1. About half (51%) of studies included
21 272 children 12 to 23 or 24 months of age, and the two next most common age ranges were 12 to 59
22 273 or 60 months of age (11%) and 0 to 59 months of age (8%).
23 274

24 275 Full vaccination was assessed in three-fourths (94, 75%) of papers; otherwise, the four most
25 276 common vaccines assessed one at a time were MCV (39, 31%), DTP (36, 29%), polio (33, 26%),
26 277 and BCG (27, 22%). There were at least 12 different definitions of full vaccination used in the
27 278 papers including in this scoping review. Of the 94 papers which evaluated full vaccination
28 279 coverage, most (66, 70%) used a traditional schedule based off of the four vaccines first
29 280 recommended for the WHO's EPI in 1974: 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose
30 281 MCV. Five (5%) papers modified this traditional definition to include a birth dose of polio, and
31 282 eleven others used a pentavalent vaccine instead of DTP (of these, 3 had a 4 dose polio
32 283 schedule, and 8 had a 3-dose polio schedule). Other papers modified the traditional definition
33 284 in order to include yellow fever (in a total of 4 papers), measles-mumps-rubella vaccine (in one
34 285 paper), or to exclude certain vaccine series, like measles, polio, or BCG. Some measure of DTP
35 286 was included in all definitions of full vaccination. No papers included information about PCV
36 287 or rotavirus vaccine as an outcome in a multivariable regression model, although one used
37 288 rotavirus vaccine as a predictor variable [107].
38 289

39 290 Four variables were used in a majority of studies. The top 10 variables used in a study (with
40 291 their relationship shown in a model) are maternal education (in 94, or 75% of studies), wealth
41 292 index (88, 70%), urbanicity (79, 63%), child's sex (73, 58%), mother's age (60, 48%), birth order
42 293 (51, 41%), delivery location (42, 34%), ANC visits (34, 27%), media exposure (33, 26%), and
43 294 paternal education (32, 26%).
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3 296 The relationship between the most commonly used predictor and vaccination outcomes is
4 297 shown in Figure 3. For most predictors there is a relatively clear relationship to vaccination
5 298 outcome. For a majority of studies, greater vaccination coverage (across any vaccination
6 299 outcome considered) was related to maternal education (in 84% of studies that considered the
7 300 variable), higher wealth index (83%), more ANC visits (76%), greater media exposure (76%), an
8 301 institutional birth (69%), and more paternal education (56%). For several predictors, a large
9 302 proportion of studies found no significant relationship. This was especially true for child's sex
10 303 (66% of studies), more paternal education (44%), and urbanicity (43%). Sibling composition was
11 304 one variable for which there was no clear relationship with the outcome: in 41% of studies,
12 305 having more older siblings was associated with lower vaccination coverage, in 8% it was
13 306 associated with higher vaccination coverage, and for the rest of studies, there was no significant
14 307 relationship (35%) or there was a significant, non-monotonic relationship (12%).
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19 309 DISCUSSION

20 310
21 311 Vaccination programs enjoy wide support from many international health organizations and
22 312 national governments. Vaccination has achieved the sole instance of human disease eradication
23 313 – smallpox, while polio, measles, and rubella have been eliminated in some regions of the world
24 314 [1,139]. Global vaccination coverage has increased in recent years but 12.8 million children in
25 315 2015 still had not yet received DTP dose 1 [6], a common marker routine immunization
26 316 initiation. Regularly conducted studies on vaccination uptake are necessary to assessing
27 317 population level susceptibility and immunization program reach while also ensuring that
28 318 countries are on track with international guidelines for maintaining high vaccination coverage
29 319 and the control or elimination of certain vaccine-preventable diseases. The DHS datasets tend to
30 320 be very large, both in number of variables looked at and number of participants surveyed. This
31 321 allows the examination of many possible associations with sufficient statistical power and the
32 322 ability to control for a number of possible confounders.
33 323

34 324 DHS is not conducted in all LMICs, only in certain countries with a USAID presence, and it is
35 325 conducted at irregular intervals. However, it is one of the most widely available surveys for
36 326 assessing vaccinations globally. This systematic review found wide variation in how full
37 327 vaccination was defined across 125 studies using DHS data between 2005 and 2018. However,
38 328 the majority of studies did look at full vaccination and defined it according to the WHO's EPI
39 329 schedule; 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose MCV. Additionally, studies
40 330 looked at similar sub-populations (children <5) and very similar predictors, with the most
41 331 common being maternal education, wealth, urbanicity, and child's sex.
42 332

43 333 The vaccines commonly evaluated reflect priorities of international efforts. For example, polio is
44 334 targeted for elimination by 2018 [140]. Measles is also subject to an international elimination
45 335 effort [141,142], and all 6 WHO regional offices have established target dates for elimination
46 336 [143]. BCG was one of the first vaccines ideally administered shortly after birth (joined more
47 337 recently in certain locations with HepB and polio birth doses). And DTP dose 3 has long been
48 338 used as a proxy for adherence to repeat visits to immunization appointments [144,145]. As more
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3 339 vaccines are added to the vaccine schedule, not only does it become more complicated, but it
4 340 likely introduces the potential for greater diversity among countries in their respective EPI
5 341 schedules. Over the past few decades, DHS has operated in 92 countries. However, a significant
6 342 number of papers came from a relatively small number of countries. We note the most
7 343 commonly used countries (India, Nigeria, Ethiopia, Pakistan, and Bangladesh) are among the 12
8 344 most populous countries in the world, and, with the exception of Bangladesh, are among the
9 345 five countries with the most number of unvaccinated children [8]. Given that countries have
10 346 control over their own vaccine policies and utilize a wide variety of socioeconomic variables
11 347 across individual countries, more country-specific analyses of DHS vaccination data is
12 348 important.

13 349 14 350 **Recommendations for future analyses**

15 351
16 352 This study identified the variables commonly used as explanatory variables in multivariable
17 353 regression models. Many studies appeared to use the DHS datasets to test the significance and
18 354 estimate the strength of association for many explanatory variables concomitantly. Since DHS is
19 355 a cross-sectional study it cannot be used to look at causal associations between variables.
20 356 However, a strength of DHS is its ability to be used as a hypothesis generating device.
21 357 Associations can subsequently be examined in other types of studies, such as cohort studies.

22 358
23 359 However, given consistent relationships between commonly used predictors and outcomes, it is
24 360 worth revisiting the use of DHS datasets in multivariable analyses. First, given this consistency,
25 361 it is more important than ever to consider the plausible causal relationships across all variables
26 362 utilized in a model. An approach widely used in epidemiology is to chart the directionality of
27 363 relationships among variables through directed acyclic graphs (DAGs) [146]. Online software,
28 364 like dagitty.net, can be used to build these models and assess which variables should be
29 365 included in the final multivariable model. A potential problem is inclusion of so many variables
30 366 in one model can obscure the mediating effects of certain variables [147]. For example,
31 367 researchers examining the relationship between media exposure and vaccination status may
32 368 include maternal age as a confounder. However, the parameter estimate for maternal age in this
33 369 multivariable model includes the mediator media exposure. Theoretically, a model with age as
34 370 the main predictor and with media exposure as a main predictor would have different sets of
35 371 covariates. Although the potential impact of inappropriately controlling for mediation is
36 372 context-specific, one study suggests parameter estimates may change up to 10%-25% [148].

37 373
38 374 Evolving immunization schedules mean that future studies will likely take local programmatic
39 375 considerations into account. However, to make cross country comparisons, studies could still
40 376 provide an estimate of full vaccination using the traditional BCG, 3 dose polio, 3 dose DTP, and
41 377 1 dose MCV schedule.

42 378
43 379 Timeliness has also emerged as an important dimension of vaccination uptake within the past
44 380 two decades [149,150]. Measures of timeliness require vaccination dates [14], information
45 381 missing from many individuals in the DHS datasets. For example, in the 2006-2007 Pakistan

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3 382 DHS EPI immunization cards, and thus data on vaccination dates, were available for just 10% of
4 383 cases [85].
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6 384

7 385 Finally, researchers analyzing DHS data should be aware of its structure and limitations. Most
8 386 DHS samples are stratified and based on clusters. Studies should use survey procedures and
9 387 weights to ensure that estimates are representative of the national population and that standard
10 388 errors are honest reflections of the sampling structure. Additionally, because DHS includes so
11 389 many individuals with unknown vaccination age, any study should account for this substantial
12 390 left censoring, through Turnbull estimation methods [151] or accelerated failure time models. A
13 391 substantial minority of studies examined did not specify the age range of the study population.
14 392 This has implications for timeliness but should be presented in studies calculating more
15 393 traditional measures of vaccine uptake that do not incorporate timing or age.
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19 395 The DHS provides national estimates from politically neutral sources, in countries where
20 396 USAID operates. Its continued existence ensures that reliable and nationally representative data
21 397 sources are publicly available. Although other surveys, like the District Level Household
22 398 Survey (DLHS) and the Annual Health Survey (AHS) in India and the Multiple Indicators
23 399 Cluster Survey (MICS) in over 100 countries, are not funded by USAID [152,153].
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26 401 **Limitations**

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29 403 There are several limitations to this study. Because the study populations, use of explanatory
30 404 variables, and definitions of outcomes differed among studies, we were unable to conduct a
31 405 meta-analysis to compare the association of various explanatory variables on outcomes. We did
32 406 not examine the grey literature or non-English language papers as part of this review, nor did
33 407 we review reports which may have listed vaccination coverage, but did not include some
34 408 statistical analysis. Inclusion of these types of articles could have included data from more
35 409 countries. Vaccination data from the DHS is limited in that it partially comes from information
36 410 contained on vaccination cards [154], and partially from parental recall – with its obvious
37 411 potential for errors. However, some countries, such as Ethiopia, have attempted to combat this
38 412 problem in recent years through the introduction of a Health Facility Questionnaire. This
39 413 questionnaire is used to record vaccination information for all children, who were discovered to
40 414 not have a vaccination card during administration of the Woman's Questionnaire [155]. In
41 415 addition, since the DHS is a standardized questionnaire there is limited opportunity to modify
42 416 the survey to be locally relevant and take predictors into account that may only be relevant in
43 417 parts of the country. However, overall the DHS programs are widely available surveys
44 418 providing researchers, policymakers, and the public with nationally representative data. These
45 419 data provide a basis for evaluation of immunization programs that would either not exist or not
46 420 be as robust in their absence.
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49 422 **Conclusions**

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3 424 This scoping review of papers about vaccination published using DHS data found diversity in
4 425 analyses and qualities of studies. Although certain countries – like India, Nigeria, Pakistan, and
5 426 Ethiopia – have had ≥ 7 vaccination studies published using DHS data, there are dozens of
6 427 countries whose vaccination data have not yet been published within single-country studies.
7 428 Studies find consistent relationships between greater vaccination uptake and more maternal
8 429 education, higher wealth index, more ANC visits, greater media exposure, and institutional
9 430 delivery. The relationship between birth order and vaccination status is more varied across
10 431 countries. Researchers using the DHS datasets should understand the limitations of using
11 432 recorded vaccination dates, and should clarify the interpretation of estimates from
12 433 multivariable analyses given the potential for mediation.
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14 447 **Competing Interests**

15 448
16
17 449 The authors declare no competing interests.
18 450

19 451 **Author contributions**

20 452
21
22 453 MLB conceived of the study design, helped interpret the data, and revised the manuscript
23 454 critically for important intellectual content. LMS and BFC downloaded manuscripts, assessed
24 455 their fit for this systematic review, abstracted data from the manuscripts, completed qualitative
25 456 synthesis, and helped revise the manuscript critically for important intellectual content. MJ
26 457 abstracted data from the manuscripts and helped revise the manuscript critically for important
27 458 intellectual content. ALW helped interpret the data, and drafted the article. All authors gave
28 459 final approval of the manuscript to be published.
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32 461 **Data sharing statement**

33 462
34 463 The data abstracted from these studies are publicly available:
35 464 <https://doi.org/10.6084/m9.figshare.12177135>
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6 896 Figure 1. Diagram of studies' selection into a scoping review of vaccination studies using the
7 897 Demographic and Health Surveys.
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9 899 Figure 2. Map of countries which have had Demographic and Health Survey (DHS) datasets
10 900 published in vaccination studies using only one country. Countries with a DHS between 2003-
11 901 2016 without studies are separately indicated.
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14 903 Figure 3. Commonly reported predictors of vaccination status used in studies using the
15 904 Demographic and Health Survey.
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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

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

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

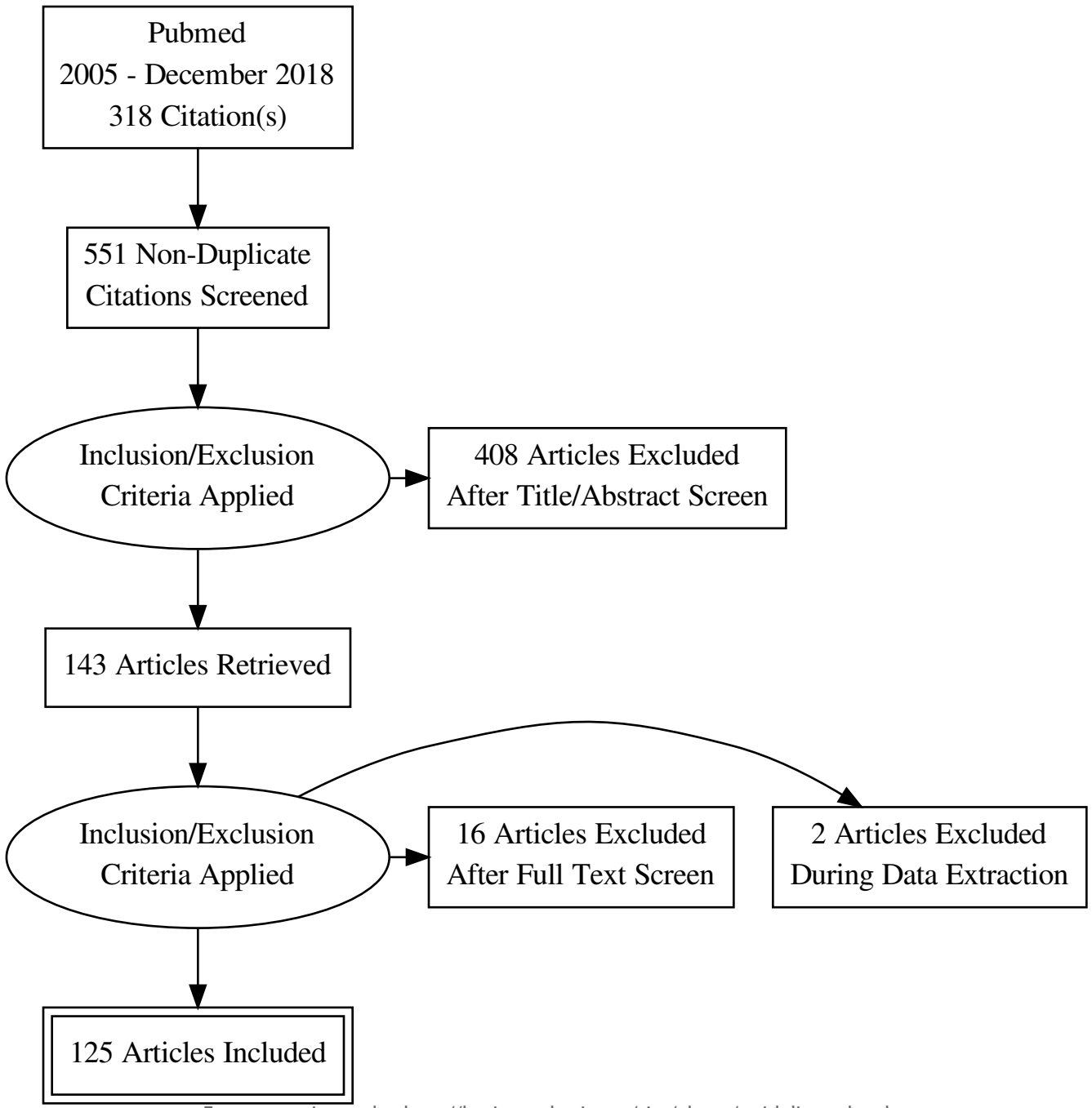
1	Ambel [110]	2017	Ethiopia	12-23 months	MCV, Full (BCG + 3DTP + 3OPV + 1MCV)	4
2	Arsenault [10]	2017	Multicountry	12-23 months	DTP, MCV	8
3	Delprato [111]	2017	Multicountry	Not specified	Full (BCG + DTP + OPV + MCV (no. unspecified))	5
4	Herliana [112]	2017	Indonesia	12-59 months	Full (BCG + 3DTP +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

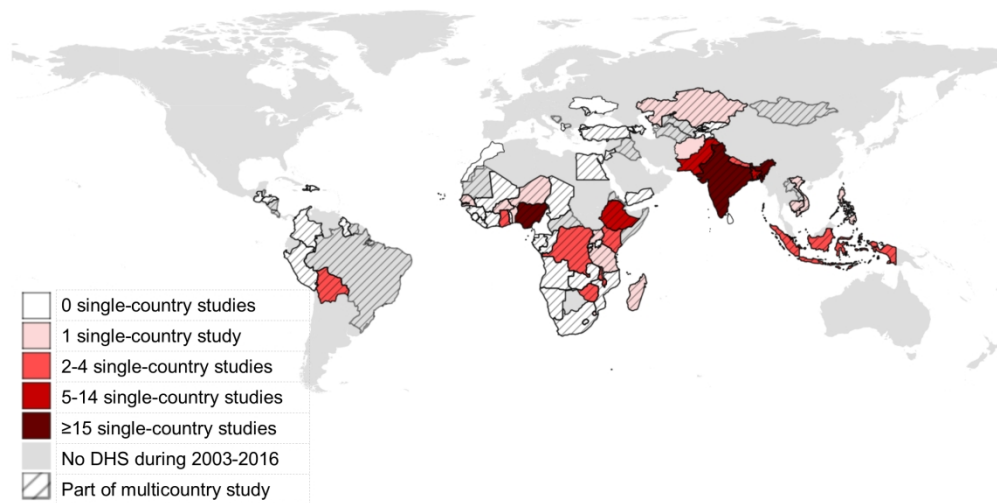
Notes:

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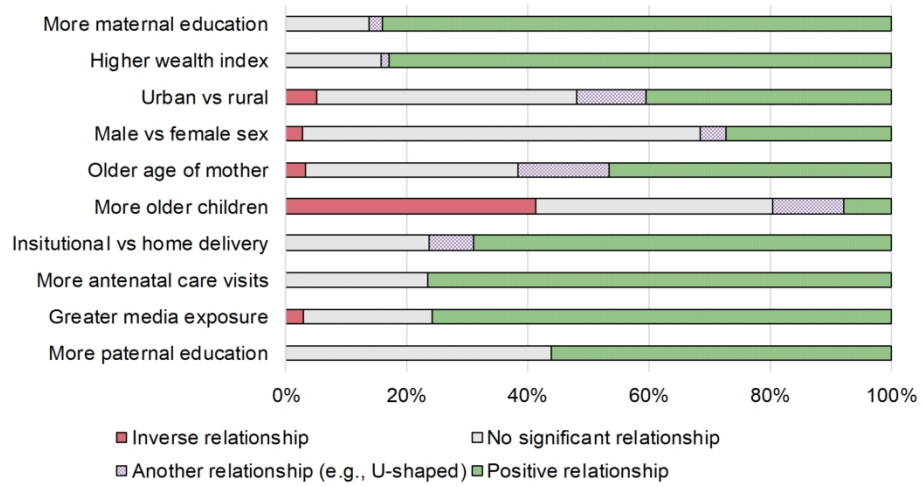




Map of countries by the number of published studies using Demographic and Health Survey (DHS) datasets. Shading corresponds to number of studies using DHS data from only one country; hash marks indicate a study using multiple countries.

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

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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 (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850).



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

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Manuscript ID	bmjopen-2020-039693.R1
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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 < PAEDIATRICALS, Public health < INFECTIOUS DISEASES, International health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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

3
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23
24 **Running Head:** Scoping review of vaccination assessments

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26
27 **Word Count:** 3,608 **Abstract:** 279

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2
3 32 **ABSTRACT**
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6 34 **Objective:** To characterize studies which have used DHS datasets to evaluate vaccination
7 35 status.
8 36

9 37 **Design:** Scoping review
10 38

11 39 **Data sources:** Electronic databases including PubMed, EBSCOhost, and POPLINE, from 2005-
12 40 2018
13 41

14 42 **Study selection:** All English studies with vaccination status as the outcome and the use of
15 43 Demographic and Health Survey (DHS) data.
16 44

17 45 **Data extraction:** Studies were selected using a predetermined list of eligibility criteria and data
18 46 was extracted independently by two authors. Data related to the study population, the outcome
19 47 of interest (vaccination), and commonly seen predictors were extracted.
20 48

21 49 **Results:** A total of 125 articles were identified for inclusion in the review. The number of
22 50 countries covered by individual studies varied widely (1 to 86), with the most published papers
23 51 using data from India, Nigeria, Pakistan, and Ethiopia. Many different definitions of full
24 52 vaccination were utilized although the majority used a traditional schedule recommended in
25 53 the WHO's Expanded Program on Immunization. We found studies analyzed a wide variety of
26 54 predictors, but the most common were maternal education, wealth, urbanicity, and child's sex.
27 55 Most commonly reported predictors had consistent relationships with the vaccination outcome,
28 56 outside of sibling composition.
29 57

30 58 **Conclusions:** Researchers make frequent use of the DHS dataset to describe vaccination
31 59 patterns within one or more countries. A clearer idea of past use of DHS can inform the
32 60 development of more rigorous studies in the future. Researchers should carefully consider
33 61 whether a variable needs to be included in the multivariable model, or if there are mediating
34 62 relationships across predictor variables.
35 63

36 64 **Keywords:** vaccine-preventable diseases; developing countries; immunization programs;
37 65 surveys and questionnaires
38 66
39 67

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3 73 **Strengths and limitations**

- 4 74 - The Demographic and Health Surveys (DHS) are some of the most used sources of
5 national-level vaccination data
6 75
7 76 - Most DHS studies find consistent relationships between sociodemographic variables
8 and vaccination outcomes.
9 77
10 78 - There are large variations in how often a country's DHS dataset is used.
11 79 - A limitation is the use only of English language material.
12 80 - Studies using other national-level vaccination surveys were not included.
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81 INTRODUCTION

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

91
92 Based on the prevalence and severity of disease and on the availability of a safe and effective
93 vaccine, the World Health Organization (WHO) recommends that countries include nine
94 vaccines on their publicly funded vaccine schedule for young children [5]. Referred to as the
95 Expanded Program on Immunization (EPI), the schedule initially recommended vaccination
96 with *Bacillus Calmette-Guérin* (BCG), diphtheria-tetanus-pertussis vaccine (DTP), polio vaccine,
97 and a measles-containing vaccine (MCV). Since 2004, five additional pediatric vaccines have
98 been added to the WHO EPI: hepatitis B vaccine (HepB), *Haemophilus influenzae* type b vaccine
99 (Hib), rubella vaccine, pneumococcal conjugate vaccine (PCV), and rotavirus vaccine.

100 Individual countries decide which vaccines to publicly fund and also to make available on the
101 private market resulting in wide variation globally in the adoption of these vaccines. For
102 example, in 2015, 194 countries included 3 doses of DTP and polio in their immunization
103 schedule whereas only 84 included rotavirus [6]. Many countries now use a pentavalent
104 vaccine, which includes DTP, HepB, and Hib vaccines in one vial. Substantial efforts on the part
105 of Gavi The Vaccine Alliance and other international agencies are devoted to logistically and
106 financially supporting the introduction of new and underused vaccines [7]. These efforts are
107 particularly important because a discouragingly high number of children consistently do not
108 receive some or all of the vaccines that were first recommended by the WHO. According to the
109 WHO, 19.4 million children have not received three doses of DTP, with a majority (11.7 million)
110 living in just 10 countries: Nigeria, India, Pakistan, Indonesia, Ethiopia, Philippines, the
111 Democratic Republic of the Congo, Brazil, Angola, and Vietnam [8]. With the exception of
112 Brazil, all of these countries have vaccination coverage regularly assessed as part of the
113 Demographic and Health Survey (DHS) program.

114
115 Nationally representative surveys, like those of the DHS program, have been essential to
116 evaluating country- and region-specific vaccination programs over time. DHS programs are
117 funded and facilitated by the US Agency for International Development (USAID). The DHS
118 program was launched in 1984 with a goal of advancing global understanding of health and
119 population trends in developing countries. Since its inception it has provided technical
120 assistance for over 300 surveys in 93 developing countries across the globe. Today, the program
121 is known for collecting and disseminating accurate, nationally representative data on a variety
122 of topics including fertility, family planning, maternal and child health, gender, HIV/AIDS,
123 malaria, and nutrition. Host countries have ownership of data collection, analysis, presentation,

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3 124 and use and the data is designed to ultimately be used in policy formation, program planning,
4 125 and monitoring and evaluation [9].
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6 126

7 127 A large number of prior studies have amalgamated data from several different DHS datasets, or
8 128 have included data from many countries, but none has systematically evaluated how these past
9 129 studies have actually used the vaccination data provided by DHS [10–12]. Given that DHS has
10 130 had widespread use over several decades in evaluating vaccination programs through
11 131 identification of under-vaccinated groups, and characterizing systematic barriers to vaccination,
12 132 a clearer idea of past use of DHS can inform the development of more rigorous studies in the
13 133 future. The purpose of this scoping review was to characterize studies which have used DHS
14 134 datasets to evaluate childhood vaccination status. Specifically we report on the global
15 135 distribution of studies, list the predictors used in multivariable regression models, and examine
16 136 the different definitions of “full vaccination” across studies and how these relate to the WHO
17 137 EPI recommendations.
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19 138

20 139 **METHODS**

21 140
22 141 This scoping review was completed by following the steps outlined by the Preferred Reporting
23 142 Items of Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR)
24 143 [13].
25
26 144

27 145 **Search Strategies**

28 146 Searches were performed in 3 different electronic databases: PubMed/MEDLINE, PopLine, and
29 147 EBSCOhost’s Africa-Wide Information, Global Health, Global Health Archives, and Health
30 148 Policy Reference Center databases. The search terms used were; “Vaccine” (and its variations
31 149 such as vaccination and vaccinate), “Immunization” (and its variations such as immunize),
32 150 “demographic and health surveys”, “demographic and health survey”, “DHS”, “National
33 151 Family Health Survey”, and “NFHS”. Within PubMed the exact search was the following:
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35 152

36 153 ("demographic and health surveys" OR "demographic and health survey" OR "DHS" OR
37 154 "National Family Health Survey" OR "NFHS") AND (immuniz* OR Vaccin*) AND
38 155 ("2000/01/01"[PDAT] : "3000/12/31"[PDAT])
39
40 156

41 157 In addition, the searches were limited to only return papers published between 1 January 2005
42 158 and 31 December 2018. References from articles found to be relevant were searched in order to
43 159 identify additional articles.
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45 160

46 161 **Eligibility Criteria**

47 162 The titles of all papers returned through use of the search terms were initially screened for
48 163 relevance. The abstracts of all remaining papers were then accessed with specific inclusion and
49 164 exclusion criteria in mind. Abstracts and manuscripts were included if they met all inclusion
50 165 criteria: (1) studies were conducted using DHS data from low or middle-income countries; (2)
51 166 studies looked at routine vaccination coverage as the primary outcome; (3) studies were cross-
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167 sectional in design; (4) studies used either the Demographic and Health Survey (DHS) or the
168 National Family Health Survey (NFHS), a similar study conducted only in India; (5) studies
169 looked specifically at the vaccination outcome of children (usually aged between 0 and 60
170 months). A set of exclusion criteria was also created: (1) studies published before 2005 or after
171 2018 (though studies with an online publication in 2018 but print publication in 2019 were
172 included); (2) studies that looked only at the vaccination outcome of adults; (3) studies that
173 looked at population in high income countries; (4) studies that used modeling or projections
174 instead of just analyzing the data provided; or (5) systematic reviews.

175

176 **Study Selection**

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

181

182 **Data extraction**

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

195

196 **Study Methodological quality evaluation**

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

200

201 **Introduction / Study population**

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

207 **Descriptive Statistics**

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

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3 209 E. Does the paper provide estimates of random variability (e.g., 95% confidence interval of
4 210 weighted estimates or standard errors) for the main outcomes? (1=Yes, 0=No)
5

6 211 **Analytical Statistics**

- 7 212 F. Does the paper use do a multivariable analysis? (1=Yes, 0=No)
8 213 G. Does the paper show distribution of confounders / covariates? (1=Yes, 0=No)
9 214 H. Does the paper describe how the researchers arrived at the final list of confounders? (2=*a*
10 215 *priori* knowledge or used directed acyclic graph (DAG), 1=used P-values from crude
11 216 analysis or used stepwise technique, 0=did not describe or did not use multivariable
12 217 analysis)
13 218 I. Does the paper write out P-values under 0.05? (1= Yes, or provided 95% confidence
14 219 intervals, 0=No)
15
16 220

17
18 221 The quality score could range from 0-10, and we describe the average values with a mean and
19 222 median quality score among all studies.
20
21 223

22 224 **Synthesis of study findings**

23 225 Given the heterogeneity of outcomes, predictors, and study populations of the included studies
24 226 it was not possible to combine the results into a meta-analysis. Instead, we present a narrative
25 227 summary of the data. We describe the distribution of studies by population, what predictor
26 228 variables are used (and what direction of association they have with outcome), and how full
27 229 vaccination is defined. In the discussion, we provide recommendations for future analyses of
28 230 DHS data.
29 231

30
31 232 A choropleth map was created using freely available shapefiles from Natural Earth [16] in QGIS
32 233 3.6 (QGIS Development Team). The map shows how many studies using data from only one
33 234 country were published by country. We also show if a country's data was part of a multicountry
34 235 study, and we identify countries which had a standard DHS dataset administered between 2003
35 236 and 2016 but which did not have a published study. The years 2003-2016 were chosen as a lag
36 237 time of 2 years compared to the scoping review inclusion criteria to account for delays in
37 238 publishing the data and writing up a manuscript.
38 239

39 240 **Patient and public involvement**

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41 241 This research was done without public involvement. Members of the public were not invited to
42 242 comment on the study design and were not consulted, nor were they invited to contribute to
43 243 this document to improve accessibility.
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245 Table 1. List of papers included in a scoping review of studies assessing vaccination status using the Demographic and Health Survey (DHS).
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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

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

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

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

Notes:

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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

For peer review only

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

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3 296 recommended for the WHO's EPI in 1974: 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose
4 297 MCV. Five (5%) papers modified this traditional definition to include a birth dose of polio, and
5 298 eleven others used a pentavalent vaccine instead of DTP (of these, 3 had a 4 dose polio
6 299 schedule, and 8 had a 3-dose polio schedule). Other papers modified the traditional definition
7 300 in order to include yellow fever (in a total of 4 papers), measles-mumps-rubella vaccine (in one
8 301 paper), or to exclude certain vaccine series, like measles, polio, or BCG. Some measure of DTP
9 302 was included in all definitions of full vaccination. No papers included information about PCV
10 303 or rotavirus vaccine as an outcome in a multivariable regression model, although one used
11 304 rotavirus vaccine as a predictor variable [107].
12 305

13 306 Four variables were used in a majority of studies. The top 10 variables used in a study (with
14 307 their relationship shown in a model) are maternal education (in 94, or 75% of studies), wealth
15 308 index (88, 70%), urbanicity (79, 63%), child's sex (73, 58%), mother's age (60, 48%), birth order
16 309 (51, 41%), delivery location (42, 34%), ANC visits (34, 27%), media exposure (33, 26%), and
17 310 paternal education (32, 26%).
18 311

19 312 The relationship between the most commonly used predictor and vaccination outcomes is
20 313 shown in Figure 3. For most predictors there is a relatively clear relationship to vaccination
21 314 outcome. For a majority of studies, greater vaccination coverage (across any vaccination
22 315 outcome considered) was related to maternal education (in 84% of studies that considered the
23 316 variable), higher wealth index (83%), more ANC visits (76%), greater media exposure (76%), an
24 317 institutional birth (69%), and more paternal education (56%). For several predictors, a large
25 318 proportion of studies found no significant relationship. This was especially true for child's sex
26 319 (66% of studies), more paternal education (44%), and urbanicity (43%). Sibling composition was
27 320 one variable for which there was no clear relationship with the outcome: in 41% of studies,
28 321 having more older siblings was associated with lower vaccination coverage, in 8% it was
29 322 associated with higher vaccination coverage, and for the rest of studies, there was no significant
30 323 relationship (35%) or there was a significant, non-monotonic relationship (12%).
31 324

32 325 **DISCUSSION**

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34 327 Vaccination programs enjoy wide support from many international health organizations and
35 328 national governments. Vaccination has achieved the sole instance of human disease eradication
36 329 – smallpox, while polio, measles, and rubella have been eliminated in some regions of the world
37 330 [1,139]. Global vaccination coverage has increased in recent years but 12.8 million children in
38 331 2015 still had not yet received DTP dose 1 [6], a common marker of routine immunization
39 332 initiation. Regularly conducted studies on vaccination uptake are necessary to assessing
40 333 population level susceptibility and immunization program reach while also ensuring that
41 334 countries are on track with international guidelines for maintaining high vaccination coverage
42 335 and the control or elimination of certain vaccine-preventable diseases. The DHS datasets tend to
43 336 be very large, both in number of variables looked at and number of participants surveyed. This
44 337 allows the examination of many possible associations with sufficient statistical power and the
45 338 ability to control for a number of possible confounders.
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340 DHS is not conducted in all LMICs, only in certain countries with a USAID presence, and it is
341 conducted at irregular intervals. However, it is one of the most widely available surveys for
342 assessing vaccinations globally. This systematic review found wide variation in how full
343 vaccination was defined across 125 studies using DHS data between 2005 and 2018. However,
344 the majority of studies did look at full vaccination and defined it according to the WHO's EPI
345 schedule; 1 dose BCG, 3 doses polio, 3 doses DTP, and 1 dose MCV. Additionally, studies
346 looked at similar sub-populations (children <5) and very similar predictors, with the most
347 common being maternal education, wealth, urbanicity, and child's sex.

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349 The vaccines commonly evaluated reflect priorities of international efforts. For example, polio
350 was targeted for elimination by 2018 [140]. Measles is also subject to an international
351 elimination effort [141,142], and all 6 WHO regional offices have established target dates for
352 elimination [143]. BCG was one of the first vaccines ideally administered shortly after birth
353 (joined more recently in certain locations with HepB and polio birth doses). And DTP dose 3 has
354 long been used as a proxy for adherence to repeat visits to immunization appointments
355 [144,145]. As more vaccines are added to the vaccine schedule, not only does it become more
356 complicated, but it likely introduces the potential for greater diversity among countries in their
357 respective EPI schedules. Over the past few decades, DHS has operated in 92 countries.
358 However, a significant number of papers came from a relatively small number of countries. We
359 note the most commonly used countries (India, Nigeria, Ethiopia, Pakistan, and Bangladesh) are
360 among the 12 most populous countries in the world, and, with the exception of Bangladesh, are
361 among the five countries with the most number of unvaccinated children [8]. Given that
362 countries have control over their own vaccine policies and utilize a wide variety of
363 socioeconomic variables across individual countries, more country-specific analyses of DHS
364 vaccination data is important.

365 366 **Recommendations for future analyses**

367
368 This study identified the variables commonly used as explanatory variables in multivariable
369 regression models. Many studies appeared to use the DHS datasets to test the significance and
370 estimate the strength of association for many explanatory variables concomitantly. Since DHS is
371 a cross-sectional study it cannot be used to investigate the effect of an exposure which could
372 vary across time, such as education or urbanicity. However, a strength of DHS is its ability to be
373 used as a hypothesis generating device. Associations can subsequently be examined in other
374 types of studies, such as cohort studies.

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

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3 382 included in the final multivariable model. A potential problem is inclusion of so many variables
4 383 in one model can obscure the mediating effects of certain variables [147]. For example,
5 384 researchers examining the relationship between media exposure and vaccination status may
6 385 include maternal age as a confounder. However, the parameter estimate for maternal age in this
7 386 multivariable model includes the mediator media exposure. Theoretically, a model with age as
8 387 the main predictor and with media exposure as a main predictor would have different sets of
9 388 covariates. Although the potential impact of inappropriately controlling for mediation is
10 389 context-specific, one study suggests parameter estimates may change up to 10%-25% [148].
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14 391 Evolving immunization schedules mean that future studies will likely take local programmatic
15 392 considerations into account. However, to make cross country comparisons, studies could still
16 393 provide an estimate of full vaccination using the traditional BCG, 3 dose polio, 3 dose DTP, and
17 394 1 dose MCV schedule.
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19 396 Timeliness has also emerged as an important dimension of vaccination uptake within the past
20 397 two decades [149,150]. Measures of timeliness require vaccination dates [14], information
21 398 missing from many individuals in the DHS datasets. For example, in the 2006-2007 Pakistan
22 399 DHS EPI immunization cards, and thus data on vaccination dates, were available for just 10% of
23 400 cases [85].
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27 402 Finally, researchers analyzing DHS data should be aware of its structure and limitations. Most
28 403 DHS samples are stratified and based on clusters. Studies should use survey procedures and
29 404 weights to ensure that estimates are representative of the national population and that standard
30 405 errors are honest reflections of the sampling structure. Additionally, because DHS includes so
31 406 many individuals with unknown vaccination age, any study should account for this substantial
32 407 left censoring, through Turnbull estimation methods [151] or accelerated failure time models. A
33 408 substantial minority of studies examined did not specify the age range of the study population.
34 409 This has implications for timeliness but should be presented in studies calculating more
35 410 traditional measures of vaccine uptake that do not incorporate timing or age.
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39 412 The DHS provides national estimates from politically neutral sources over time, in countries
40 413 where USAID operates. Its continued existence ensures that reliable, comparable, and nationally
41 414 representative data sources are publicly available. Other surveys, like the District Level
42 415 Household Survey (DLHS) and the Annual Health Survey (AHS) in India and the Multiple
43 416 Indicators Cluster Survey (MICS) in over 100 countries, are developed in close collaboration
44 417 with DHS [152,153].
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48 419 **Limitations**

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50 421 There are several limitations to this study. Because the study populations, use of explanatory
51 422 variables, and definitions of outcomes differed among studies, we were unable to conduct a
52 423 meta-analysis to compare the association of various explanatory variables on outcomes. We did
53 424 not examine the grey literature or non-English language papers as part of this review, nor did
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3 425 we review reports which may have listed vaccination coverage, but did not include some
4 426 statistical analysis. Inclusion of these types of articles could have included data from more
5 427 countries. Vaccination data from the DHS is limited in that it partially comes from information
6 428 contained on vaccination cards [154], and partially from parental recall – with its obvious
7 429 potential for errors. However, some countries, such as Ethiopia, have attempted to combat this
8 430 problem in recent years through the introduction of a Health Facility Questionnaire. This
9 431 questionnaire is used to record vaccination information for all children, who were discovered to
10 432 not have a vaccination card during administration of the Woman’s Questionnaire [155]. In
11 433 addition, since the DHS is a standardized questionnaire there is limited opportunity to modify
12 434 the survey to be locally relevant and take predictors into account that may only be relevant in
13 435 parts of the country. However, overall the DHS programs are widely available surveys
14 436 providing researchers, policymakers, and the public with nationally representative data. These
15 437 data provide a basis for evaluation of immunization programs that would either not exist or not
16 438 be as robust in their absence.
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22 440 **Conclusions**

23 441
24 442 This scoping review of papers about vaccination published using DHS data found diversity in
25 443 analyses and qualities of studies. Although certain countries – like India, Nigeria, Pakistan, and
26 444 Ethiopia – have had ≥ 7 vaccination studies published using DHS data, there are dozens of
27 445 countries whose vaccination data have not yet been published within single-country studies.
28 446 Studies find consistent relationships between greater vaccination uptake and more maternal
29 447 education, higher wealth index, more ANC visits, greater media exposure, and institutional
30 448 delivery. The relationship between birth order and vaccination status is more varied across
31 449 countries. Researchers using the DHS datasets should understand the limitations of using
32 450 recorded vaccination dates, and should clarify the interpretation of estimates from
33 451 multivariable analyses given the potential for mediation.
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15 467
16 468 **Competing Interests**

17 469
18 470 The authors declare no competing interests.

19 471
20 472 **Author contributions**

21 473
22 474 MLB conceived of the study design, helped interpret the data, and revised the manuscript
23 475 critically for important intellectual content. LMS and BFC downloaded manuscripts, assessed
24 476 their fit for this systematic review, abstracted data from the manuscripts, completed qualitative
25 477 synthesis, and helped revise the manuscript critically for important intellectual content. MJ
26 478 abstracted data from the manuscripts and helped revise the manuscript critically for important
27 479 intellectual content. ALW helped interpret the data, and drafted the article. All authors gave
28 480 final approval of the manuscript to be published.

29 481
30 482 **Data sharing statement**

31 483
32 484 The data abstracted from these studies are publicly available:
33 485 <https://doi.org/10.6084/m9.figshare.12177135>

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6 917 Figure 1. Diagram of studies' selection into a scoping review of vaccination studies using the
7 918 Demographic and Health Surveys.

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9 920 Figure 2. Map of countries by the number of published studies using Demographic and Health
10 921 Survey (DHS) datasets. Shading corresponds to number of studies using DHS data from only
11 922 one country; hash marks indicate a study using multiple countries.

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14 924 Figure 3. Commonly reported predictors of vaccination status used in studies using the
15 925 Demographic and Health Survey.

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For peer review only

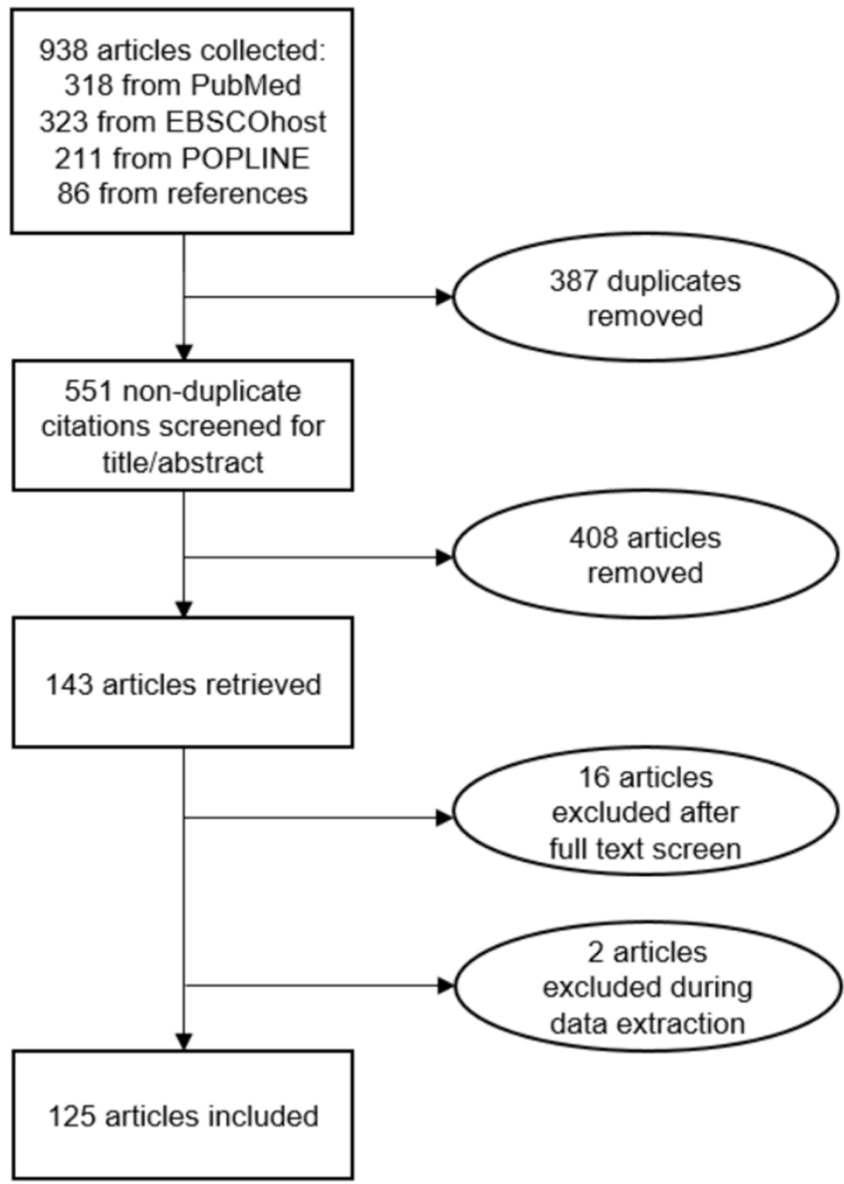
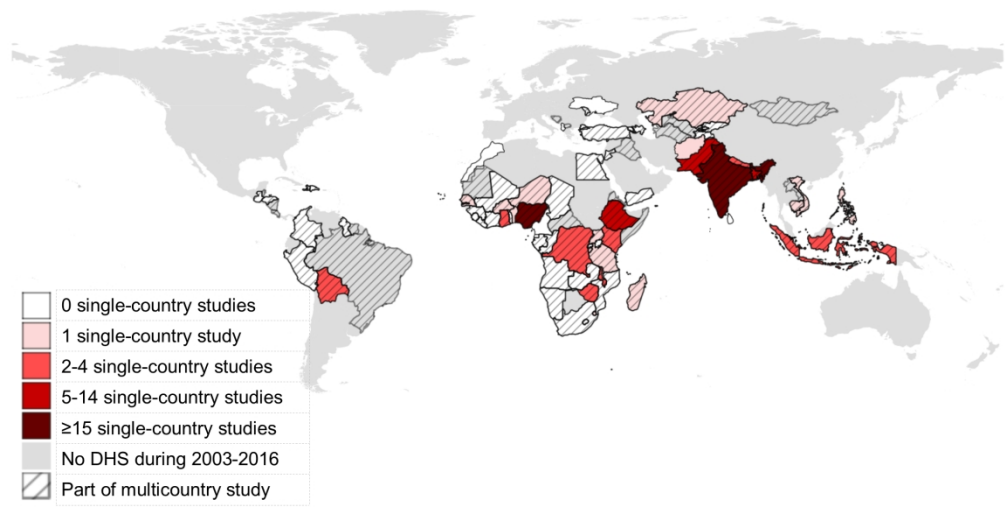


Diagram of studies' selection into a scoping review of vaccination studies using the Demographic and Health Surveys.

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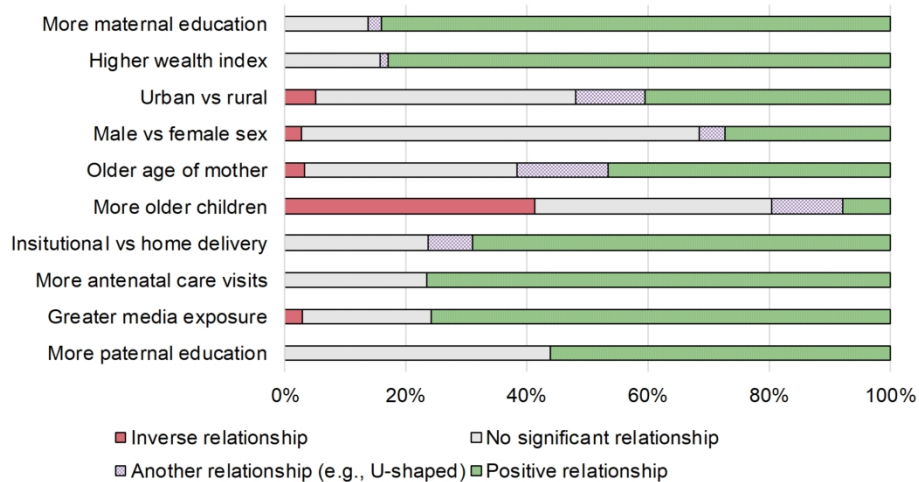
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Map of countries by the number of published studies using Demographic and Health Survey (DHS) datasets. Shading corresponds to number of studies using DHS data from only one country; hash marks indicate a study using multiple countries.

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

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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 (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850).



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