Inequity in Childhood Immunization in India: A Systematic Review

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Background: Despite a reduction in disease burden of vaccine-preventable diseases through childhood immunization, considerable progress needs to be made in terms of ensuring efficiency and equity of vaccination coverage.

Objective: To conduct a systematic review to identify and explore factors associated with inequities in routine vaccination of children in India.

Methods: Publications reporting vaccination inequity were retrieved through a systematic search of Medline, and websites of the WHO, UNICEF and demographic health surveys in India. No restrictions were applied in terms of study designs. The primary outcome measure was 'complete vaccination/immunization' defined as per the standard WHO definition.

Results: There were three nation-wide data sets *viz.* the three National Family Health Surveys (NFHS), a research study conducted by the Indian Council of Medical Research (ICMR) and a UNICEF coverage evaluation survey. In addition, several publications representing different population groups or geographic regions were available. A small number of publications were re-analyses of data from the NFHS series. There is considerable inequity in vaccination coverage in different states. Within states, traditionally poor performing states have greater inequities, although there are significant inequities even within better performing states. There are significant inequities in childhood vaccination based on various factors related to individual (gender, birth order), family (area of residence, wealth, parental education), demography (religion, caste), and the society (access to health-care, community literacy level) characteristics. Girls fare uniformly worse than boys and higher birth order infants have lower vaccination coverage. Urban infants have higher coverage than rural infants and those living in urban slums. There is an almost direct relationship between household wealth and vaccination rates. The vaccination rates are lower among infants with mothers having no or low literacy, and families with insufficient empowerment of women. Paternal literacy has an inconsistent positive relationship with infant vaccination. There is a relationship between religion and caste and childhood vaccination. Access to health services and other infrastructure, is associated with better vaccination coverage of infants. The precise impact of specific risk factors operating singly or in combination cannot be calculated from this systematic review.

Conclusion: This systematic review identifies and explores factors associated with inequity in childhood immunization in India; and provides information for urgent action to redress the imbalances.

Keywords: Children, Equity, Immunization, India, Vaccine preventable diseases.

India was one of the first countries to adopt the World Health Organization's Expanded Programme of Immunization (EPI). The program started globally in 1974 and was initiated in India in 1978. Since its inception, considerable progress has been made in terms of reduction in disease burden. Despite these achievements and tremendous advances in economic and technological spheres in recent years, the burden of vaccine-preventable diseases remains unacceptably high, in comparison to developed countries and also many developing countries [1]. One of the obvious reasons for this could be that the level of coverage with individual vaccines does not meet the target of sustained high coverage required to control/eradicate disease. However vaccination coverage data released by official sources such as the Ministry of Health and Family Welfare [2] and Indian Council of Medical Research [3], consistently suggested acceptably high levels of vaccine coverage in India. In contrast, independent sources such as joint WHO-UNICEF (United Nations Children's Fund) report revealed 20-30% differences from the official data for each vaccine in the national program. More recently, the National Family Health Survey (NFHS) series [4-6] have shown that the true vaccination coverage (estimated by robust methodological procedures) is actually even lower than formerly believed. Over and above this, the tendency to present vaccination performance in terms of average coverage rates raises yet another problem *viz.* the issue of equity. Averages often mask the wide disparity between extremes; in the case of childhood vaccination in India, this is especially true as the range for all observations is extremely high. As an example, the latest NFHS report [6] gives the national average for complete vaccination as 43.5%; however this masks the fact that performance in states like Tamil Nadu with 81% coverage is vastly different from states like Nagaland with 21% coverage.

Pande and Yazbeck [7] demonstrated the importance of looking beyond national average figures for childhood vaccination to uncover disparities masked by the average. They described significant heterogeneity between states and highlighted the north-south imbalance. They used the term 'total system failure', to describe uniformly low vaccination coverage across all population segments in some states. They recognized that some states could have high overall vaccination performance but significant inequities; in contrast there could be states with low performance but greater equity.

Gaudin and Yazbeck [8] also reiterated that average values do not reflect the true picture or provide information for action; they were concerned about the relationship between "efficiency" and "equity". The former term is a euphemism for performance, in other words the overall vaccination coverage; whereas the latter describes the distribution of vaccination across different groups. Their analysis of NFHS-2 data [5] revealed areas that had more equitable distribution of vaccination coverage, but very low overall coverage (high equity but low efficiency). Enhancing efficiency (coverage) in such areas might increase inequities. They therefore advocated using Wagstaff's extended achievement index (comprising inequality-adjusted immunization scores) rather than vaccination coverage alone, to allow examination of both efficiency and equity.

Equity in immunization should not be restricted to merely creating equal opportunities for immunization of children within the country (in a sense this already exists as vaccination is provided free-of-cost to all infants all over the country through a vast network of public sector institutions). It is also concerned with identifying the groups at highest risk of remaining unvaccinated and bridging gaps/imbalances as far as possible. In this regard, the NFHS surveys [4-6] have provided a vast body of data on the immunization status of infants grouped by various individual, family, and social characteristics. The need of the hour is to systematically examine all sources of data reflecting inequities in vaccination. Such an exercise would be beneficial in identifying the groups of infants at highest risk of remaining unvaccinated; and also the characteristics of infants with high as well as low vaccination coverage status. However no such document is currently available.

This systematic review of literature was undertaken to identify inequity in childhood routine immunization in India; and to explore the reasons for the same.

METHODS

Study design: This was a descriptive systematic review of literature pertaining to childhood vaccination with specific emphasis on examining and exploring the issues of equity and inequity in childhood immunization. No secondary data analysis (meta-analysis or other statistical tests) was undertaken. The design corresponded to previously used Methodology for this kind of research question [9].

Inclusion criteria

Types of publications: This was a broad-based review and included all types of publications (available in the public domain) reporting childhood vaccination in India by direct data collection through surveys, interviews, research trials, etc or secondary analysis of published data obtained through one or more of these methods. Publications representing estimations, data extrapolations, or employing other indirect methods to calculate childhood vaccination such as consumption of vaccine doses, administrative databases, financial logs, etc were not included. No restriction was applied in terms of type of study, methodology employed, type of data analysis, or peer-review of publications. Where multiple sets of data were available through serial updates, the most current publication was included.

Types of participants: Publications were included if they contained data on childhood vaccination. The definition of child/childhood was age group less than five years. Vaccination/immunization pertained to vaccines in the National Immunization Schedule, *viz.* BCG at birth, three doses of DPT and OPV at 6, 10 and 14 weeks; one dose of measles vaccine at 9 months of age; and booster doses at 18 months and 5 years. The National Immunization Schedule also includes a booster dose of tetanus toxoid (TT) at 10 years of age and 2 doses tetanus toxoid vaccination of pregnant women. However publications describing these were not included as they do not directly pertain to the focus of this review. Similarly, publications on vaccines that are currently not in the National Schedule (such as hepatitis B, MMR, and newer vaccines) were not included.

Types of outcome measures: The primary outcome measure was 'complete vaccination/immunization' defined as per the 1998 World Health Organization (WHO) guideline *viz.* receipt of one dose of BCG vaccine, three doses of DPT and OPV vaccines, and one dose of measles vaccine by infants in the age group 12-23 completed months. Secondary outcome measures were (*i*) 'no vaccination/ immunization' defined as failure of an infant 12-23 months old to receive even a single dose of the vaccines listed above, and (*ii*) 'partial/incomplete vaccination/ immunization' defined as receipt of vaccine doses between 'no vaccination' and 'complete vaccination'.

Search methods for identification of studies: The following databases were searched: Medline through Pubmed (www.pubmed.com) on 27 November 2011 and updated during 6-12 December 2011. Websites of the World Health Organization, United Nations Children's Fund (UNICEF), Demographic and Health Survey (DHS) series, and Ministry of Health and Family Welfare, were searched between 12 and 27 December 2011. In addition, reference lists of included publications were searched to discover additional data. No attempt was made to obtain unpublished data, or data unavailable in the public domain, or data available within specific institutions at the national, state or local level. Publications were selected for potential inclusion by screening titles (first step), screening abstracts of relevant titles (second step) and studying the full text of relevant abstracts (third step). At this stage, decision to include or exclude a publication was made.

Search strategy: A Pubmed MeSH search for the term "equity" returned two categories *viz.* "Tax Equity and Fiscal Responsibility Act" (1985), and "The remuneration paid or benefits granted to an employee" (1978). As neither of these terms was relevant to this systematic review, additional MeSH search for the term "Disparity" was undertaken; this returned three categories *viz.*. "Vision Disparity" (1989), "Healthcare Disparities" (2008) and "Health Status Disparities" (2008). The last term "Health Status Disparities" was relevant and hence explored further, yielding 13 subheadings; amongst these, the following were considered relevant: "statistics and numerical data, trends, utilization". Therefore the following search string was used to include citations related to disparity: "(("Healthcare Disparities/statistics and numerical data"[Mesh]) OR "Healthcare Disparities/ trends"[Mesh]) OR "Healthcare Disparities/ utilization"[Mesh]". This was combined with terms for immunization/vaccination and India; using the search string: "(immuniz* OR vaccin*) AND India*". An additional search for the specific terms 'equity' and 'inequity', combined with vaccination/immunization in India was undertaken using the string "(vaccin* OR immuniz*) AND India* AND (equit* OR inequit*)". Following this, a series of searches was undertaken using specific terms for gender, wealth/poverty, area of residence, social and socio-economic factors. The detailed search strings for these searches are listed in ***Table*** I.

RESULTS

The output of the multiple Medline searches, and the step-wise screening for inclusion of publications, is summarized in ***Table* I**. Website searches yielded the three NFHS reports [4-6] and four additional reports from different Departments of the Ministry of Health and Family Welfare [10-13]. Searching of multiple WHO [14,15] and UNICEF [16-19] websites did not yield any additional publications that could be included. Searching reference lists of included publications yielded one additional publication.

TABLE 1 OUTLINE OF THE TERMS, STRINGS, STRATEGY AND OUTPUT FOR SEARCH AND STEP-WISE DECISION TO INCLUDE/EXCLUDE PUBLICATIONS

Search for:	*Search string*	*Search strategy*	*Titles*	*Abstracts*	*Full-text*	*Included*
Disparity in vaccination	"((immuniz* OR vaccin*) AND India*) AND ("Healthcare Disparities/statistics and numerical data"[Mesh] OR "Healthcare Disparities/trends" [Mesh]) OR "Healthcare Disparities/utilization" [Mesh]	Web Appendix 1	25	1	1	1
Equity/inequity in vaccination	(vaccin* OR immuniz*) AND India* AND (equit* OR inequit*)]	Web Appendix 2	22	6	6	6
Gender	(immuniz* OR vaccin*) AND India* AND gender	Web Appendix 3	47	27	14	9
Area of residence	(vaccin* OR immuniz*) AND India* AND (rural OR urban OR slum)	Web Appendix 4	615	76	29	14
Wealth OR poverty	(immuniz* OR vaccin*) AND India* AND (Wealth OR poverty)	Web Appendix 5	150	41	18	7
Social factors	(immuniz* OR vaccin*) AND India* AND (social OR socio*)	Web Appendix 6	496	71	31	8
Education or literacy	(immuniz* OR vaccin*) AND India* AND (education* or literacy)	Web Appendix 7	582	96	38	9
Incentives	(immuniz* OR vaccine*) AND incentive AND India*	Web Appendix 8	42	3	0	0

There were a limited number of publications reporting nation-wide data; these were the three Demographic Health Surveys [4-6], a survey conducted by the Indian Council of Medical Research (ICMR) [3] at the invitation of the Ministry of Health and Family Welfare in 1999; and three reports from the Ministry of Health and Family Welfare [10-12]. Recently the Ministry of Health and Family Welfare and UNICEF, jointly published the results of a Coverage Evaluation Survey undertaken during November 2009 to January 2010 [13]; this represents the most current nationwide data available. This survey evaluated the vaccination status of 12-23 month old infants drawn from rural (*n*=12635) and urban (*n*=9969) areas. The methodology used was fairly similar to the NFHS surveys.

Some common trends were noted in the NFHS-3 report [6] and other documents. The coverage for individual vaccines was much higher than the proportion of "fully vaccinated" infants; suggesting significant decline in coverage for each subsequent dose of DPT / OPV and between the third dose of DPT/OPV and measles vaccine; suggesting that coverage rates declined as infants grew older. Another interesting observation is that although DPT and OPV doses are administered at the same age (and therefore ideally at the same vaccination session), there was a consistent difference between the coverage for the two vaccines.

Another important observation from the three NFHS series [4-6] is the trend over time. In the NFHS-1 survey (1992-93), a total of 35.4% infants were fully vaccinated and about 30.0% had not received any vaccination. The second survey (NFHS-2, 1998-99) reported that 42.0% infants were fully vaccinated and 14.4% had not received any vaccination. NFHS-3 reported 43.5% full vaccination and 5.1% infants with no vaccination. These data show that although there was no significant recent progress in complete vaccination of infants, many infants are partially immunized. When the data from the UNICEF 2009-10 survey [13] are considered, there appears to be dramatic progress in vaccination coverage; the complete vaccination rate was 61.0%. ***Figure* 1** summarizes the data. Further consideration of time-trends and overall vaccination are outside the scope of this review. The following sections discusses major factors responsible for inequities in childhood vaccination.

State-level differences

NFHS-3 data [6] showed that nine states had full vaccination rate lower than the national average; these include Madhya Pradesh, Jharkhand, Meghalaya, Bihar, Assam, Arunachal Pradesh, Rajasthan, Uttar Pradesh and Nagaland. The below-average coverage states include highly populous states such as Uttar Pradesh.

A group of Indian researchers [62] analyzed NFHS-3 data further to calculate state-wise disparities by gender and area of residence, for 4 indicators of child health *viz.* complete vaccination, prevalence of underweight children, prevalence of diarrhea and under-five child mortality. To evaluate the effect of wealth, the authors plotted the concentration curve (CC) and calculated the concentration index (CI). The former plots the cumulative population shares of a particular characteristic against the cumulative outcome (wealth quintiles from lowest to highest) on the *x*-axis and cumulative complete vaccination on the *y*-axis. If the resulting curve is not a straight line, it indicates inequity in the health-care outcome (here complete vaccination). The concentration index is calculated as twice the area between the diagonal (representing zero inequity) and the actual curve plotted. The larger the value of the CI, the greater the degree of inequality. They reported that states with the highest concentration index (indicating greatest wealth-based inequities) were Bihar, Assam, Madhya Pradesh, Rajasthan, Jharkhand and Uttar Pradesh. Only 8 of 18 states had a coverage rate greater than 50%. The authors also plotted concentration indices for other health-care measurements including under-five mortality, prevalence of underweight and prevalence of diarrhea; the results indicated the same finding.

Analysis by area of residence showed that rural children were the least likely to have complete vaccination. This inequity was high in states like Madhya Pradesh, Rajasthan, Chhattisgarh, Jharkhand and Uttar Pradesh. Interestingly, the highest inequity between rural and urban areas existed in Kerala, followed by Chhattisgarh and Haryana. A similar analysis by gender was also undertaken, which suggested the worst imbalance existed in Bihar and Punjab, followed by Madhya Pradesh and Uttar Pradesh.

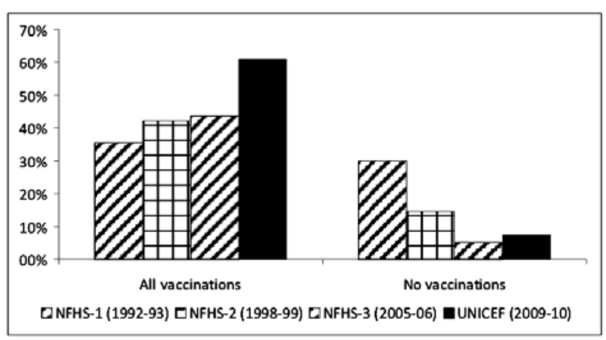

FIG 1 *Vaccination trend over time (Data from the three NFHS series and latest UNICEF coverage evaluation survey).*

The ICMR survey [3] conduced across 90 districts in India during 1999 reported 13 states with complete vaccination coverage higher than the national average of 63.3%. Only BIMARU (Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh) and north-east states had coverage lower than the national average. For some reason, the north-east states were not named individually; likewise a group loosely labelled "Union territories and others" were reported to have 82% complete vaccination coverage. These data showed inexplicably higher vaccination coverage than the NFHS-2 data for the same time period.

Another nation-wide survey conducted by the Health Ministry among 4320 infants (distributed equally among rural and urban areas) [11] reported that 56.6% infants were fully vaccinated, compared to 50% the preceding year. Nearly one-fifth infants had not received any vaccination. Among the 18 surveyed states reported, over 85% complete vaccination was noted in only three states *viz.* Tamil Nadu (91.5%), Kerala (91.3%) and Maharashtra (84.7%). Six states (West Bengal, Punjab, Madhya Pradesh, Karnataka, Delhi and Andhra Pradesh) reported 70-85% complete vaccination. However, complete vaccination by the age of 12 months was over 80% only in Kerala and Maharashtra. The states with lowest vaccination coverage included Bihar (12.8% complete and 58.0% unvaccinated), Rajasthan (19.7% complete and 38.2% unvaccinated), Uttar Pradesh (26.7% complete and 45.4% unvaccinated), and Jharkhand (25.7% complete and 39.3% unvaccinated). It must be noted that no data on north-east states were presented.

The 2009-10 UNICEF survey [13] reported that 16 of 29 states had complete vaccination rate higher than the national average of 61.0%; the Union Territories combined together had 71.3% complete vaccination. Four states had greater than 80% complete vaccination; these were Goa (87.9%), Sikkim (85.3%) Punjab (83.6%), and Kerala (81.5%). The lowest rate was noted in Arunachal Pradesh (24.8%) and Nagaland (27.8%). Barring these two states, all the other states had full vaccination rates above 40%. Even the traditionally poor-performing states showed dramatically improved performance; complete vaccination rates in Bihar (49.0%), Madhya Pradesh (42.9%), Rajasthan (53.8%) and Uttar Pradesh (40.9%) were much higher compared to previous surveys a few years prior [11,12].

In a document titled, 'National Health profile 2005' [10], the Central Bureau of Health Intelligence (CBHI), Directorate of Health Services of the Ministry of Health and Family Welfare, published data on vaccination coverage during the period 1998-99. The document reported complete vaccination among 42.0% and no vaccination in 14.4% infants. Although the methodology of obtaining vaccination data was not clearly described, state-wise coverage for the same period was reported. The disparity in complete vaccination ranged from 11.0% in Bihar to 83.4% in Himachal Pradesh. No clear regional pattern could be discerned from the data. For example, among the north-east states, Assam (complete vaccination 17.0% and no vaccination 33.2%), Nagaland (complete vaccination 14.10% and no vaccination 32.7%), and Meghalaya (complete vaccination 14.3% and no vaccination 42.3%) appear to be very different from Mizoram (complete vaccination 59.6% and no vaccination 10.5%) or Arunachal Pradesh (complete vaccination 20.5% and no vaccination 28.7%). The best state performance was reported from Goa (complete vaccination 82.6% and no vaccination 0.0%) and Himachal Pradesh (complete vaccination 83.4% and no vaccination 2.8%). Maharashtra and Kerala had very low rates of non-vaccination (2.0% and 2.2% respectively); although complete vaccination rate was short of 80% in both states. No coverage data were reported for 6 Union Territories.

A survey independent of the NFHS [20] compared the vaccination status of infants (12-32 months) in four BIMARU states of north India (Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh) with the status in India as a whole. A cluster-survey was undertaken in 30 districts comprising 900 villages (6300 children). Complete vaccination rate was only 48% compared to 63% for India; and these 4 states accounted for 70% of India's unvaccinated children although they have only 40% of the total population. As in other studies, vaccination rates were lower among infants with illiterate mothers and residing in rural areas. The proportion of completely unvaccinated infants was highest in Bihar (28%). The overall proportion of unvaccinated children in the four states (22%) was twice the national average. The imbalances between boys *vs* girls, rural *vs* urban, scheduled caste/tribe *vs* others, and illiterate *vs* literate parents; for complete vaccination coverage as well as unvaccinated infants was similar in the BIMARU states as all over India.

De also re-examined NFHS-2 data to determine the factors affecting childhood vaccination in Madhya Pradesh, Bihar, Uttar Pradesh and Rajasthan [21] where the demographic, health and social indicators (infant mortality rate, total fertility rate, female literacy, women employment, maternal prenatal care, and institutional deliveries) are worse than the national average. He evaluated vaccination coverage in terms of receipt of three doses of DPT and OPV. Complete vaccination of infants (rural and urban) in these states was worse than the national average. The inequities in these four states were similar to those for the national situation; however in Madhya Pradesh, there was somewhat better vaccination coverage among Muslims than other social groups.

A group of international researchers [22] tried to identify the factors influencing the disparity in childhood vaccination in two Indian states *viz.*. Maharashtra and Bihar. These were selected as they were similar in population size, but diverse in terms of development, economic status, health indicators (such as infant mortality and life expectancy), and administrative systems. The investigators evaluated the vaccination status of over 3000 children in the age group 1-3 years old. They reported that almost two-thirds of children in Maharashtra were fully vaccinated; whereas this only about 10% in Bihar. The authors attributed these differences to more educated parents in Maharashtra, higher use of prenatal services, better media exposure and higher standard of living. Interestingly, this study showed that the probability of complete vaccination was higher for children in rural areas of Maharashtra than urban areas, and attributed this to better rural health care services in the state.

Mohanty, *et al.* [23] compared childhood vaccination by household economic status in Uttar Pradesh with Maharashtra. Using NFHS data, they observed wide variation in complete vaccination between Maharashtra and Uttar Pradesh. However, the rich to poor gap estimated by calculation of the concentration index increased over time in both states suggesting that even in better-performing states such as Maharashtra, there was significant inequity based on economic status.

Effect of Gender

There was a higher proportion of boys (53%) than girls surveyed in NFHS-3 [6]. The complete vaccination rate was 45.3% for boys and 41.5% for girls. This gender imbalance existed irrespective of the method of determination of vaccination status; among those whose vaccination card was examined, 38.8% boys and 36.1% girls were fully vaccinated. There were 4.3% boys compared to 6.0% girls who had not received any vaccination. The gap between the genders was about 5% for most of the individual vaccines including BCG, DPT (all three doses) and measles; however the gap between boys and girls was considerably less for the three doses of OPV (about 2%). ***Fig*. 2** depicts a summary of the NFHS-3 data for different vaccines.

A group of researchers evaluated gender differences by examining data from the three NFHS surveys as well as other studies [24]. They pooled the data and calculated a relative probability of vaccination among girls of 0.93 (95% CI 0.90-0.98), suggesting a 7% lower likelihood. Analysis of the serial NFHS survey data suggested that the overall gender inequity did not increase over time. Six states with vaccination coverage higher than the national average, were among the 8 states with the lowest proportion of vaccinated girls. While the overall girl to boy vaccination coverage ratio was 0.95 for India as a whole; it varied from 0.86-0.90 in Punjab, Haryana and Bihar. In Uttar Pradesh and Delhi, the ratio was 0.92 and 0.93 respectively. Among the northern states, Himachal Pradesh and Rajasthan had the most favorable girl to boy ratio. In the south, the best gender ratio was observed in Tamil Nadu and Kerala. In the North-east, Jharkhand and Assam had the most favourable coverage for girls; although the total coverage was very low.

The 2009-10 UNICEF survey [13] reported complete vaccination in 61.9% boys and 59.9% girls; the unvaccinated infants were 7.9% and 7.2% respectively. The UNICEF (2005) survey across 22 states (including combined data for 7 north-east states) reported complete vaccination among 53.9% female infants compared to 55.1% males [12]; however no tests for statistical significance were performed. The Ministry of Health and Family Welfare coverage evaluation survey during 2001-02 [11] reported fully vaccinated boys and girls as 58.0% and 55.1% respectively; however no statistical analysis was undertaken. The ICMR survey (1999) [3] reported 64.2% and 62.2% complete vaccination among boys and girls respectively; and no vaccination among 9.1% and 10.3% boys and girls respectively.

Vaccination data of 1279 infants in the age range 1-3 years in West Bengal state was examined from the District Level Household Survey under the Reproductive and Child Health project (2002-2004) [25]. It showed 54% complete vaccination rate. Although there was wide

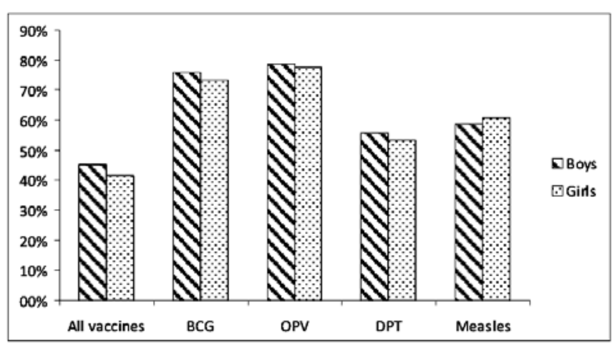

FIG 2 *Gender-based inequity in childhood vaccination (data from NFHS-3 survey).*

variation in vaccination rates across 18 districts (range 23.3% to 72.2%); full vaccination was 53.0% among boys and 54.7% among girls; odds ratio 1.061 (95% CI not given).

A research study undertaken in 3 of 6 districts in Assam state in 2003 [26] evaluated vaccination status of infants based on examination of vaccination cards and maternal recall. Standard 30-cluster sampling method was used to collect data for 616 infants between 1-2 years of age. Complete vaccination was higher among male infants (64.6%) compared to females (59.3%). An econometric analysis of vaccination data obtained from a sample of over 4333 rural children between 1-2 years old reported 50% fully vaccinated girls compared to 55% fully vaccinated boys [27]. A survey evaluating measles incidence and vaccination coverage in urban slums in Ahmedabad during the year 2000 [28] included over 3000 eligible children using standard 30-cluster sampling. It reported total measles vaccine coverage of 60% but did not find gender inequalities. The authors also reported the measles incidence rate and found no disparity between boys and girls. This confirmed the absence of gender-based disparity for measles vaccine.

A small study to assess the vaccination status of 1-2 year old infants in Goa [29], included 362 infants using 30-cluster sampling method. The proportions of boys who were fully vaccinated, partially vaccinated and unvaccinated were 84.6%, 13.8% and 1.6% respectively; it was 86.2%, 9.8% and 4.0% for girls. However the author did not report the absolute number of infants in each group.

A survey carried out in Surat city [30] to calculate the incidence of measles among children below the age of five years collected measles vaccination data of 2597 children (9 months to 5 years), using parental recall and examination of immunization cards. The overall coverage rate in boys was 49.3% compared to 47.2% among girls. Although the overall difference was not statistically significant; analysis by age of children revealed gender-based differences among younger infants. Thus 33.7% boys in the 9-11 month age group were vaccinated, compared to 26.1% girls; likewise 52.9% boys and 46.2% girls in the age group 1-2 years were vaccinated. The gap narrowed with increasing age; 52.3% boys and 49.8% girls in the 2-3 year age group were vaccinated. Beyond that age, the gender differences narrowed further and a slightly higher percentage of 4-5 year old girls had been vaccinated.

Srivastava and Nayak [31] presented a brief report of gender bias in vaccination coverage in Patna, the capital of Bihar state during the years 1983-1990. However, the results were presented graphically and numerical data could not be extracted.

Birth order

The NFHS-3 data [6] showed a trend of declining vaccination with increasing birth order (***Fig. 3***). The proportion of fully vaccinated infants by birth order was 54.6% (first order), 45.3% (second or third), 29.9% (fourth or fifth) and 18.5% (sixth or higher). The proportion of unvaccinated infants also showed a direct relationship; 3.7% among first order, 4.7% among second/third order, 7.0% among fourth/fifth, and 8.6% among sixth/higher order. Since the NFHS-3 data presented combined data for birth orders 2 and 3; and 4 and 5; information on each of these could not be obtained separately. There was also no statistical analysis to confirm the risk associated with higher birth order. Analysis of coverage for individual vaccines (***Fig. 4***) highlights two points: the coverage for OPV is higher than for DPT as observed previously; and the gaps between increasing birth orders is much lower for OPV compared to all the other vaccines.

The 2009 Coverage evaluation survey [13] reported complete vaccination among infants with birth order 1, 2,

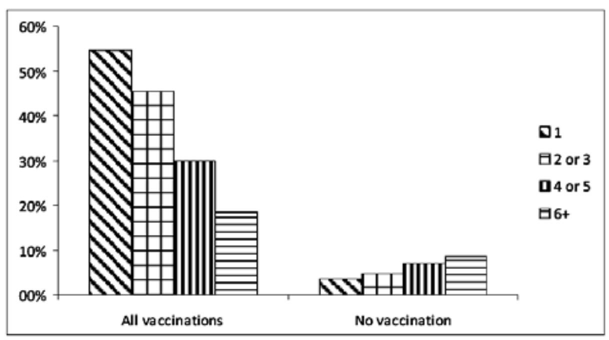

FIG 3 *Relationship of birth order and childhood vaccination (data from NFHS-3 survey).*

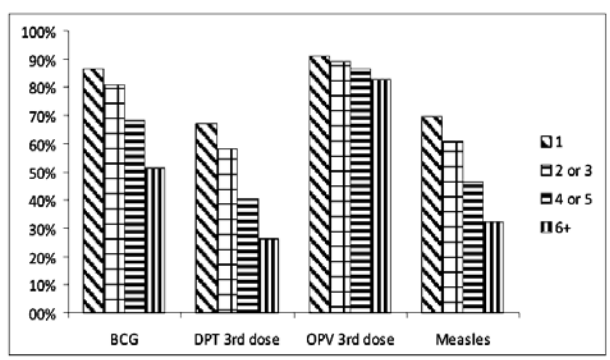

FIG 4 *Coverage of individual vaccines and relationship to birth order (data from NFHS-3 survey).*

3, 4+ as 67.4%, 64.7%, 53.7%, and 40.4% respectively. The proportion of unvaccinated infants was 4.4%, 6.7%, 10.8%, and 16.0% respectively.

Analysis of the three NFHS surveys [24] showed that although higher birth order infants had lower vaccination coverage, girls were particularly disadvantaged. Among third birth order infants with two older sisters, only 36.1% girls received age-appropriate vaccination compared to 45.0% boys. However, third birth order girls with two older brothers had slightly higher rates than boys in the same situation.

In a survey of vaccination status of children dwelling in urban slums in Agra city [32], nearly two-thirds of unvaccinated infants had birth orders two or greater. Interestingly, among 228 fully vaccinated infants also, nearly half had birth order two or higher. The unadjusted and adjusted (for gender and age of child) relative probability of complete vaccination was significantly lower for second and third birth order infants compared to first birth order infants; 0.52 (95% CI 0.36-0.76) and 0.67 (95% CI 0.40-1.13) respectively.

A small-scale survey in Goa [29], also reported lower proportion of fully vaccinated infants with higher birth order; it was 86.6%, 88.8%, 69.2% and 75.0%; for birth orders 1, 2, 3 and 4 respectively. The respective proportion of unvaccinated infants was 1.1%, 2.0%, 7.6% and 25.0%. The author did not report absolute numbers of children in each group.

Pande [33] studied the effect of the gender of older siblings on the gender-imbalance in rural areas. She reviewed NFHS-1 data and reported that first birth order boys had 38% complete vaccination compared to 36% in first birth order girls. The complete vaccination rate of infants with one older sister was 35% among boys and 31% among girls; the rates were identical for boys and girls with two older sisters. For boys with one older brother, the rate was 35%; the corresponding rate for girls was 32%. Interestingly, infants with two older brothers had significantly lower vaccination rates; 22% for boys and 26% for girls.

Residential Area (Urban, Rural and Urban Slum)

The NFHS-3 survey [6] reported that 57.6% of urban infants were fully vaccinated compared to 38.6% in rural areas. The percentage of infants who were not vaccinated was 5.7% in rural areas compared to 3.3% in urban areas. The urban-rural gap existed for all individual vaccines, although the gap was lowest with the 3 doses of OPV. No statistical analysis was carried out in the NFHS-3 report.

The UNICEF 2009-10 survey [13] recorded complete vaccination in 58.5% rural infants compared to 67.4% urban infants; the respective unvaccinated infants were 8.5% and 5.2%. The ICMR (1999) survey [3] evaluating vaccination status of 19000 infants across India also reported a rural-urban imbalance in complete vaccination (urban 71.7% *vs* rural 58.5%) as well as no vaccination (rural 11.9% *vs* urban 5.7%).

A secondary analysis of NFHS-3 data [34] showed that among infants residing in urban areas, there were statistically significant differences in vaccination coverage (BCG, first dose of DPT, third dose of DPT, and measles) by gender, maternal education level, maternal occupation, (not working *vs* working), partner's occupation (unemployed/labour *vs* salaried/professional), regularity of occupation (all-year *vs* seasonal/occasional), caste and religion. Binary logistic regression analysis to calculate the independent effect of these variables (the dependent variable was "ever had vaccination") showed a statistically significant effect of maternal education; no education or incomplete primary education OR 0.238 (95% CI 0.079-0.718); primary education OR 0.304 (95% CI 0.097-0.954). However, middle/incomplete secondary education showed OR 0.969 (95% CI 0.311-2.968). The other statistically significant effect was found for 'mother's autonomy' (defined as "mother has no money for own use"); OR 0.627 (95% CI 0.408-0.962). There was no statistically significant independent effect of infant's gender, wealth category, caste, religion, maternal occupation, partner's occupation, or regularity of employment.

The UNICEF nation-wide survey (2005) [12] sampled 30 rural and 15 urban clusters across 22 states (the 7 north-east states were clubbed together) and reported complete vaccination rate of 47.4% in rural areas compared to 67.8% in urban areas. The respective proportion of unvaccinated infants was 18.4% and 7.9%. In terms of timeliness, only 39.3% infants were completely vaccinated before the first birthday.

The Department of Family Welfare survey (2002) [11] reported complete vaccination among 50.3% infants in rural areas compared to 74.4% in urban. The respective data for non-vaccinated infants was 23.7% and 8.9% (national average 19.8%).

A small survey in Kerala [35] compared vaccination rates in three areas; urban, semi-urban and rural. The literacy rate in all the three areas was above 90%. Standard 30-cluster sampling of infants 12-23 months old was done and vaccination cards were examined. The complete vaccination rates in the urban, semi-urban and rural area were 77.5%, 76.7% and 77.3% respectively. The respective proportions of unvaccinated infants were 4.2%, 1.9% and below 1%. Although coverage rates of

BCG and DPT/OPV were close to 90% or higher in the three areas, measles vaccination was highest in the semi-urban area (90.6%) compared to 77.9% in urban and 79.0% in rural areas.

In Goa state 80% infants residing in rural areas were fully vaccinated compared to 90.6% infants living in urban areas [29]; however the author did not define urban and rural in the study.

A survey carried out in Chandigarh Union Territory used maternal recall to assess vaccination status of infants (12-23 months) attending pulse polio booths on a National Immunization Day [36]. A sample was drawn from 20 urban booths, 16 booths in slums and 4 rural booths to approximate Chandigarh's population distribution is 50% urban, 40% in slums and resettled colonies and 10% in rural areas. The respective proportion of fully vaccinated infants was 80%, 59%, and 83%; and proportion of unvaccinated infants was 2%, 27%, and 4%.

Another survey in Chandigarh assessed the vaccination status of 12-23 month old infants [37] from 30 clusters (18 urban, 9 slum, and 3 rural) selecting 40 households from each. The population distribution was 78% in urban areas, 12% in slums and 10% in rural areas. The proportion of fully vaccinated infants was 30% in slums, 74% in rural areas and 62.5% in urban areas. As in other surveys, there was significant drop-out rate between initiation of vaccination with BCG to third dose of DPT and measles vaccine.

A vaccination coverage survey in West Bengal [25] documented complete vaccine coverage of 48.9% in rural areas and 63.9% in urban areas. Low coverage was observed among the vulnerable groups of poor minorities, especially in rural areas. Another survey in 3 districts of Assam [26] reported complete vaccination among 85.9% infants in urban areas compared to 58.7% in rural areas.

Nearly two decades back, a survey [38] in New Delhi evaluated the vaccination status of children in Narela region having both rural (population 236000) and urban (population 221000) zones. Thirty clusters were selected and immunization data of 422 infants (12-23 month old) was recorded. Complete vaccination (defined in this study as BCG and three doses of DPT and OPV) was 70.0% in rural area and 73.1% in the urban area. Coverage of individual vaccines in the rural and urban zones was respectively 83.8% and 88.7% for BCG, 75.7% and 78.8% for third dose of DPT; and 34.3% and 39.2% for measles vaccine.

A community based, cross-sectional survey in two urbanized villages in East Delhi among 2-4 year old children [39] collected vaccination data by house-to-house visits. In this study "urbanized village" was defined as those with population greater than 4000, or population density greater than 400 per square kilometre, or greater than 75% males employed in activities other than agriculture. Incidentally, both the selected areas had Health Centers where weekly vaccination sessions were held. Immunization cards were examined to ascertain the vaccination status; if unavailable, maternal recall was used. Among 693 children, the survey did not find any differences in complete vaccination rates between children living in nuclear or joint families; or skilled or unskilled paternal occupation. An interesting finding was that while only 34.6% infants delivered at home were fully vaccinated; 58.2% of those born in hospitals had received complete vaccination; the odds ratio was 2.64 (95% CI 1.86 to 3.75). The survey also reported that 68.2% infants with immunization cards were fully vaccinated compared to only 27.7% children who did not have cards; odds ratio 5.78; 95% CI 4.05 to 8.25.

A study examined the vaccination status of 746 children (<2 years old) among migrant families in Delhi through a 30-cluster cross-sectional survey [40] in 23 slums and 7 resettlement colonies. They further classified the families as either 'recent migrants' (migrated to Delhi within the preceding 5 years) or 'settled migrants' (migrated to Delhi more than 5 years prior). Both groups had similar demographic profiles in terms of origin, ethnicity, social class and religion. Vaccination status was determined by examining vaccination cards and if unavailable, maternal report. The overall vaccination coverage among migrant families was lower compared to 83.2% among non-migrant residents of Delhi (although the authors did not measure this directly). Complete vaccination was recorded in 64.3% recent migrant infants and 80.8% in settled migrant infants (adjusted OR for settled migrants 1.93, 95% CI 1.18-3.14). Similarly, coverage with individual vaccines was lower among recent migrant families; additionally the difference between settled and recent migrants was smaller for initial vaccines than those administered later. Thus, 92.6% recent migrant infants and 89.9% settled migrant infants had received BCG; whereas 66.2 % and 77.1% of recent and settled migrant infants had received three doses of DPT. For measles, 67.3% recent migrant infants were vaccinated compared to 82.0% of settled migrant infants.

Analysis of factors affecting vaccination status showed better complete vaccination rate with maternal education status (adjusted OR for >6 years formal education compared to no education was 4.04, 95% CI 2.04-8.00), higher maternal age (adjusted odds ratio for mothers older than 30 years compared to less than 30 years was 4.47, 95% CI 1.47-14.15); regular salaried employment of heads of families (adjusted odds ratio 5.44, 95% CI 1.76-16.77). Another significant finding was that mothers who had received prenatal care had more completely immunized infants; adjusted odds ratio for 1-2 antenatal visits *vs* no visits was 2.34 (95% CI 1.17-4.67), and for more than 3 visits 3.89 (95% CI 2.07-7.31). Another finding was a beneficial effect of postnatal visits by health-care personnel; the odds of complete vaccination was 2.74 (95% CI 1.42-5.28) compared to no postnatal visits.

A cross-sectional survey [41] to evaluate missed immunization opportunities and reasons for non-vaccination in 32 slums of Udaipur city, included 262 infants (9-24 months old) using 30-cluster sampling. Vaccination cards and maternal recall were used to determine vaccination status. The survey recorded 36% complete vaccination; 18% infants were unvaccinated. The individual vaccine coverage was 79% for BCG, 80% for first dose of DPT and 50.6% for measles vaccine. However, the contemporary coverage in urban (non-slum) areas was not described to make comparisons.

A survey in slums of Lucknow city during 2005 [42] used 30-cluster sampling with 17 infants (12-23 months old) per cluster. Immunization cards and maternal reports were used to confirm vaccination status. Multinomial logistic regression showed that low socioeconomic status (OR=10.8), Muslim religion (OR=4.3), higher birth order (OR=4.3), home delivery (OR=3.6) and belonging to a joint family (OR=2.1) were independent predictors of non-vaccination.

A small cross-sectional survey in Orissa [43] evaluated vaccination status of 71 infants (<2 years old) among migrant tribals living in slums of Bhubaneswar city. None of the infants was completely immunized and 25.3% had not received any vaccine. The overall coverage for BCG was 59%, first dose DPT 62%, 3 doses DPT 23.6% and measles vaccine 15%.

A multi-indicator cluster sampling procedure was used in 1999 to evaluate vaccination coverage of 300 infants in 15 of 299 urban slums in Surat, where about 40% of the population resides in slums [44]. Vaccination cards (maternal recall if unavailable) were used to estimate vaccination coverage. The overall complete vaccination rate was 25%. While coverage for three doses of BCG as well as OPV and DPT were higher among boys, measles vaccine coverage was slightly more among girls (32.8 % *vs* 27.8 %).

Effect of Poverty and Wealth (Economic Status)

The NFHS-3 survey [6] classified economic status of families using the 'wealth index' defined as a composite score comprising living standard based on assets (such as television sets, bicycles etc) and characteristics such as type of construction, access to water, sanitation system etc. The wealth index was then used to divide the population into wealth quintiles. The survey report showed that infants in families with higher wealth indices had better vaccination status (***Fig.* 5**), although there was no statistical analysis of the data.

A re-analysis of the NFHS-3 data [34] reported that 40% infants among the urban poor (*viz.* lowest wealth index quartile) were fully vaccinated; this was statistically significantly lower than the 65.4% fully vaccinated non-poor children (upper three wealth index quartiles). These differences between the urban poor and non-poor existed for infants who did not receive the first dose of DPT (taken to represent children left out of the immunization program), as well as those who did not receive the third dose of DPT (representing children who dropped out from the immunization program).

The UNICEF 2009-10 survey [13] also reported a direct relationship between the economic status of families and vaccination coverage; the respective complete vaccination rate in the ascending order of wealth quintiles was 47.3%, 61.8%, 66.4%, 70.0%, and 76.5%. The unvaccinated infants in the five quintiles were 13.7%, 6.3%, 4.2%, 4.7%, and 2.7% respectively. This survey also reported complete vaccination rate among families with and without BPL (below poverty line) cards; it was 60.22% and 61.4% respectively. The unimmunized infants were 7.2% and 7.9%, respectively.

Gaudin, *et al.* [8] used concentration ratios comparing cumulative population characteristics such as wealth with cumulative vaccination coverage. They then used this method to compare data from the first (1992-93) and second (1998-99) NFHS surveys to estimate the changes over time. They reported that in 1999, there were fewer areas where children did not receive any

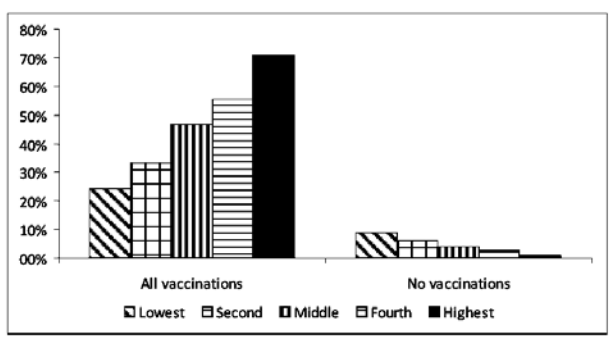

FIG 5 *Vaccination coverage by wealth quintiles (data from NFHS-3 survey).*

vaccination (reflecting total system failure); the decline was from 38% to 18% in rural areas; and 17% to 6% in urban areas. However, although wealth-based inequalities decreased in urban areas, it did not change significantly in rural areas. This suggests that less wealthy people in villages had lower vaccination rates. In rural areas, although vaccination coverage increased, much of this occurred in wealthier segments of the population.

A group of researchers addressed whether improving trends in immunization coverage over time could actually mask greater inequities between different segments of population. They re-analysed NFHS-3 data and calculated an adjusted score against the backdrop of average health status of the population and wealth strata [63] and showed that poor child health is mostly concentrated in poor households; and the highest impact of increasing average immunization coverage rates occurred in wealthier households. The adjusted score for full immunization rate actually declined for many of India's southern states which are generally at the top end of the immunization rankings. The data showed inequalities in child health achievement in states with better health status such as Kerala and Goa; and states with higher economic status such as Punjab and Haryana. The traditionally poor performing states such as Rajasthan, Uttar Pradesh, Bihar, Orissa, Chhattisgarh and Madhya Pradesh, showed a mixed pattern. Some smaller states like Jharkhand, Sikkim, Manipur and Arunachal Pradesh showed evidence of better equity but comparatively lower average. There were only two states *viz.* Tamil Nadu and Himachal Pradesh that showed progress in terms of both equity and achievement.

Mohanty, *et al.* [23] analysed NFHS data for trends in childhood vaccination, by household economic status. The economic status was calculated from consumer durables, land size, housing quality and water and sanitation facilities of the household. The concentration index was used to calculate the gap between wealthier and less wealthy households. The complete vaccination coverage of infants in the three NFHS surveys was 36%, 40% and 44%. However the absolute immunization coverage as well as rate of change was much lower among the lowest wealth quintile; it was 18%, 23% and 24% during the three surveys. The coverage in the three surveys among second lowest wealth quintile was 27%, 34% and 33% respectively. In contrast, coverage for the wealthiest quintile was not only higher than less wealthy households in each of the surveys, but also showed a rising trend over time; it increased from 64% (NFHS-1) to 71% (NFHS-3).

The UNICEF 2005 survey used the type of dwelling unit as an indirect reflection of household economic status [12]. Among families living in *kachcha* houses, complete vaccination was noted in only 40.9%; it was 57.5% in those living in semi-*pucca* houses and 65.3% among infants living in *pucca* houses.

In a study based in Udaipur district of Rajasthan [45], vaccination status of 2365, under-five children presenting to primary health centers for curative services, was analysed by household economic status (determined by the possession of assets and amenities). In addition to vaccination status, access to piped water was also assessed. Overall only 40% of 12-23 month old infants were completely vaccinated; the coverage by ascending order of wealth quartiles was 19%, 29%, 46%, and 68% respectively; the trend existed for all individual vaccines except OPV. Although there was a direct relationship between maternal literacy rate and immunization, literacy was itself associated with socioeconomic status. The literacy rate in the ascending order of wealth-based quartiles was18%, 42%, 72%, and 92%, showing that women from wealthier families were more likely to be literate. The survey also reported a negative relationship between vaccination and distance of the family from health-care centers; however it was observed that less wealthy families lived farther away from primary health-care facilities than more wealthy counterparts. These observations suggest that household economic status is a significant determinant of childhood vaccination.

The survey carried out throughout the state of West Bengal [25] evaluated the impact of living standard; complete vaccination was 44.6% among those with low standard of living; 58.0% for medium standard; and 77.1% with high standard of living. In another study [27] of infants (1-2 years old) residing in rural areas, the proportion of complete immunization was 45% in poor households and 55% in non-poor households. In this study, households were classified as "poor" if the total annual household income was below the poverty line income.

A survey in Goa [29] categorised household socio-economic status into 5 unspecified grades; 100% infants in Class I families were fully immunized; the proportions in other classes were 95.8% in Class II; 92.1% in Class III, 81.7% in Class IV; and 48.6% in Class V.

Education or Literacy

Mother's education status was assessed in the NFHS-3 survey [6]; there was higher complete vaccination and lower non-vaccination among infants of mothers with more years of formal education (***Fig. 6***). However, no statistical analysis was done.

There was a significant positive correlation between maternal education and complete vaccination in the

UNICEF 2009-10 survey [13]; 45.3% with no maternal education, 55.4% with <5 years, 64.9% with 5-7 years, 64.9% with 8-9 years, 74.1% with 10-11 years, and 76.6% with >12 years education. The corresponding unvaccinated infants were 14.3%, 9.0%, 5.1%, 3.8%, 2.1% and 2.0%.

There was a direct relationship between level of parental education and vaccination status in the UNICEF survey (2005) [12]. Only 38.2% of illiterate parents were completely vaccinated, compared to 53.8% with less than 5 years of school education, 59.6% with 5-7 years, 69.9% with 8-10 years, 77.5% with 11-12 years; and 82.4% among infants whose parents had more than 12 years of schooling.

The Department of Family Welfare survey in 18 states [11] also reported a positive relationship between complete vaccination of infants and literacy level of primary care-givers, as follows: illiterate (31.4%), 1-4 years education (64.4%), 5-8 years (71.3%), 9-14 years (85.5%) and over 15 years (96.7%).

The ICMR 1999 survey [3] reported complete vaccination rate of 46.4% among infants of illiterate mothers compared to 64.9% among mothers with primary education, 70.4% with middle education, and 78.8% with higher secondary maternal education. Paternal literacy also showed a similar relationship; complete vaccination was 45.8% among infants of illiterate fathers; 59.32% with primary education, 63.2% with middle education and 69.7% with higher secondary education. The survey also observed an effect of combined literacy of both parents; complete vaccination rate was 42.2% infants if both parents were illiterate, 65.4% if only mother was literate. 50.3% if only father was literate and 74.4% with both parents literate.

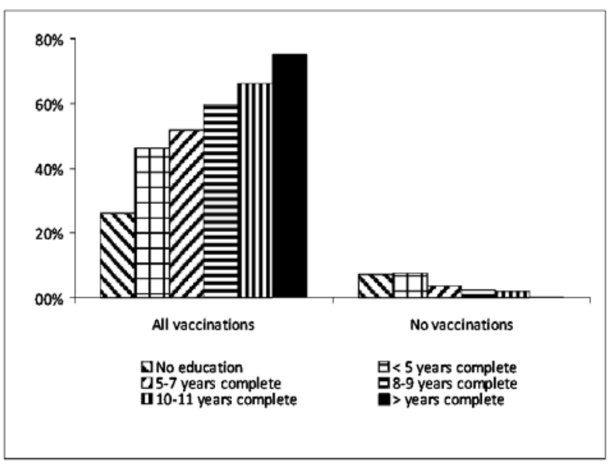

FIG 6 *Vaccination coverage by education/literacy (data from NFHS-3 survey).*

An analysis of over 4000 children living in rural households in 16 states [27] showed that 66% infants of literate mothers, 59% of infants with proximate literacy, and 42% infants of illiterate mothers were fully vaccinated. However, the authors did not describe definitions for the three categories.

In a cross-sectional study of 693 children (2-4 years) [39] in two urbanized villages in Delhi, 34.4% children of mothers with no education had received complete vaccination. In contrast, 48.1% and 50.7% children of mothers who had been educated for 1-8 years and more than 8 years, respectively were fully vaccinated. The respective odds ratios (compared to no education) were 1.77 (95% CI 1.12-1.28) and 1.96 (95% CI 1.37-2.81). Likewise only 31% of children whose fathers were uneducated were fully vaccinated compared to 33.7% and 45.7% where paternal education was 1-8 years and greater than 8 years respectively. The respective ORs were 1.30 (95% CI 0.61-2.1) and 1.80 (05% CI 1.21-2.89). The adjusted OR for complete vaccination was 1.43 (95% CI 1.03-1.99) for literate versus illiterate mothers; and 1.10 (95% CI 0.75-1.60) for literate versus illiterate fathers; suggesting that maternal literacy was a more important determinant of childhood vaccination.

A survey in Goa [29] reported that amongst uneducated mothers, 70.8% infants were fully vaccinated. In contrast, 91.2%, 90.7% and 100% of infants of mothers with primary, secondary and graduate level of education respectively had received complete vaccination. The proportion of fully vaccinated infants showed a gradation with paternal education; 56% infants of uneducated fathers were fully vaccinated, compared to 75.3% with primary level, 89.8% with secondary level and 98.5% with graduate level education.

A survey in West Bengal [25] reported complete vaccination among 61.2% infants with literate mothers and 37.8% with illiterate mothers; it was 59.9% for infants of literate fathers and 37.6% with illiterate fathers. A survey evaluating vaccination among 616 infants in the age group 1-2 years [26] reported higher complete vaccination with literate fathers (66.3% compared to 35.4% with illiterate fathers) and mothers (68.8% compared to 37.9% among illiterate mothers).

A survey in Agra's slums [32] reported that over three quarters of 699 unvaccinated infants had illiterate mothers. Even among fully vaccinated infants, about 42% mothers were illiterate. The relative probability of complete vaccination for infants of illiterate mothers compared to mothers with secondary level education was 0.08 (95% CI 0.05-0.13) unadjusted and 0.18 (95% CI 0.10-0.30) adjusted for maternal age and occupation.

Among the unvaccinated infants, 92% had mothers who were not working. This was similar to the proportion in the fully vaccinated group as well. The relative probability of complete vaccination among infants of working mothers was 0.37 (95% CI 0.18-0.77) unadjusted and 0.48 (95% CI 0.21-1.08) adjusted for maternal age, and education, suggesting that maternal education was a more critical factor than employment.

A survey in Udaipur district [45] reported complete vaccination rate of 20% among infants with illiterate mothers, 27% with less than 5 years education, 42% with 5-7 years education, and 70% among mothers with more than 8 years education.

One investigator based in the USA postulated an association not only between childhood vaccination and maternal literacy at the individual level, but also overall maternal literacy at the community (district) level [46]. She undertook hierarchical linear modelling, using the Human Development Profile Index (1994) representing individual characteristics and the Indian Census (1991) for the community characteristics; to evaluate within and between social phenomena. The former provided vaccination data of 5623 infants (1-2 years) and the latter information on literacy rates, wealth, level of urbanization, etc for 412 districts (rural and urban). Modelling showed a significant positive relationship between the proportion of literate females (defined in the Indian census as ability to read and write in any language) in a district and the likelihood of complete vaccination of a child. Further modelling controlled for 6 district-level characteristics representing economic status, access to health-care, social class, and religion. The positive relationship between district level of female literacy and complete vaccination of individual children persisted. The author then undertook modelling after controlling for literacy status of individual mothers and noted that the positive relationship between district-level literacy persisted although the magnitude was somewhat lower. In other words, infants are more likely to be fully vaccinated if their mothers are literate and they also reside in an area with overall high female literacy. In the modelling exercise, the impact of district level female literacy was overcome by higher educational attainment of individual mothers; suggesting that infants with highly educated mothers had better vaccination even if the district-level literacy was not as impressive.

As in other studies, there was a positive relationship between wealth status and likelihood of complete vaccination; and significant negative relationship with the proportion of Muslims and also scheduled tribes in a district. After controlling for individual factors, modelling suggested that residing in predominantly Muslim areas increased the likelihood of not getting completely vaccinated even for non-Muslim infants, those with literate mothers, and residing in wealthier households. This was in contrast to caste based disparities; where the effect of residing in an area with predominantly scheduled tribe households, did not increase the likelihood of individual non-scheduled tribe children being incompletely vaccinated. In other words, belonging to scheduled tribe was more important for incomplete vaccination, than residing in a disproportionately scheduled tribe area.

Based on these data, the author argued that community characteristics (especially district-level of female literacy and wealth) affect childhood vaccination in addition to individual characteristics.

Effect of Social Factors (Religion, Caste, Women Empowerment)

The NFHS-3 survey [6] defined the religion of infants by that of the head of the family. In general, complete vaccination coverage was higher among Christians and Sikhs; however the rate of non-vaccination was also higher among these groups. Muslim households had lower complete vaccination coverage and higher non-vaccination than Hindu families (***Fig.* 7**). There was no analysis to confirm statistical significance. The survey [6] also reported that infants from general category families had higher vaccination coverage that those from scheduled caste, scheduled tribe and other backward classes (***Fig* 8**). No statistical analysis as reported.

UNICEF coverage evaluation survey 2010 [13] reported 58.9% complete vaccination rate among infants from scheduled caste families, 49.8% among scheduled tribe, 60.6% among other backward caste, and 66.3% among other castes. The non-vaccination rate was 7.8%, 9.9%, 8.6% and 5.5% respectively. Vaccination rate by religion showed complete vaccination in 61.2% Hindu infants, 55.7% Muslim infants, 78.2% Sikh infants, 65.6% Christian infants, and 76.6% infants of other religions.

The previous UNICEF survey (2005) [12] reported complete vaccination coverage of 52.2% and 53.3% among infants from scheduled caste and scheduled tribe families respectively; it was 57.6% among other groups. In rural areas complete vaccination rate among infants from scheduled caste or tribe families was 46.1% compared to 48.3% amongst other infants. The corresponding data for urban areas was 69.4% among scheduled caste or tribe families; and 67.0% amongst other families. The survey reported higher rate of

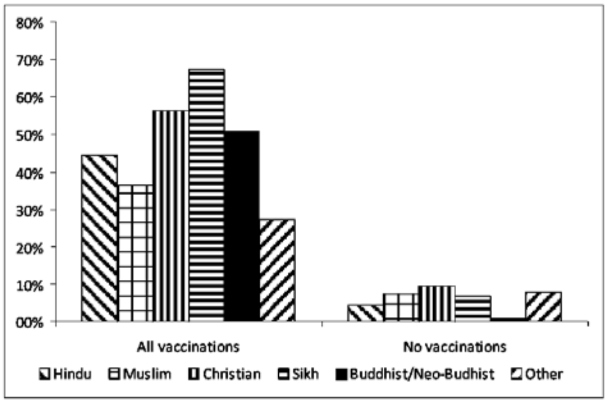

FIG 7 *Vaccination coverage by religion (data from NFHS-3 survey).*

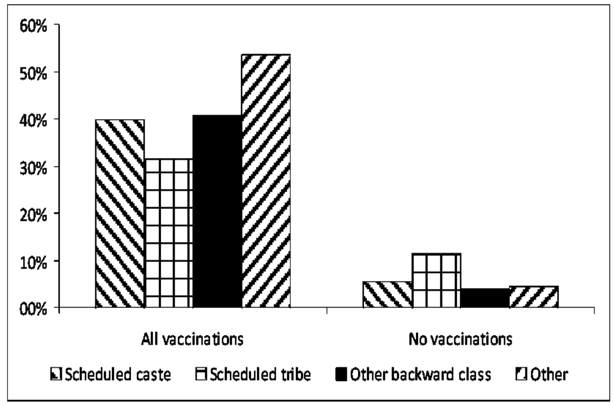

FIG 8 *Vaccination coverage by caste (data from NFHS-3 survey).*

complete vaccination amongst infants from Sikh (81.9%) and Christian (67.3%) households compared to Hindu (55.4%) and Muslim (45.5%) families.

The Department of Family Welfare survey [11], reported highest proportion of complete vaccination amongst Sikh families (71.4%), followed by Christian (65.9%), Jain (61.8%), Hindu (56.9%) and Muslim (47.2%) infants. The survey also reported 54.0% complete vaccination among infants in scheduled caste families, 51.7% among scheduled tribe and 58.1% amongst other families.

In the 1999 ICMR survey across 90 districts [3], there was a relationship between caste and complete vaccination (scheduled caste 58.9%, scheduled tribe 48.3% and others 67.2%) as well as no vaccination (scheduled caste 11.3%, scheduled tribe 16.3% and others 8.0%). However, there did not appear to be significant inequity based on religion (proportion of fully vaccinated infants was 63.8% among Hindus, 61.9% among Muslims, 65.1% among Sikhs, and 59.6% among Christians).

Another survey [27] of over 4000 children in 16 states showed that 60% infants from Hindu households were fully vaccinated compared to 40% in Muslim households. A comparison of households with and without empowered females showed complete immunization in 61% and 46% infants respectively. The definition of female empowerment was the opportunity to read newspapers, listen to the radio, or watch television; for at least 1–2 days per week.

A survey in Goa [29] reported that 83.7% infants in Hindu households were fully vaccinated whereas 2.4% were unimmunized, compared to 56.0% and 16.0% in Muslim households.

A vaccination coverage survey in West Bengal [25] reported 68.2% complete vaccination among Hindu general caste, 47.5% among Hindu scheduled caste/tribe, and 57.1% among Hindu other backward class. It was 39.8% among Muslims; and 50.0% among people of other religions. A 30-cluster vaccine coverage survey covering half of Assam's districts [26] reported higher complete vaccination among infants from Hindu households (62.5%) than Muslim households (55.9%). The authors also reported lower complete vaccination among families belonging to scheduled caste, schedule tribe and tea garden caste; as compared to general caste.

A group of researchers undertook house-to-house visits in 10 small (population <1000) and large (population 1000-22000) villages in Vikas Nagar area (population approximately 200000) [47]. Hindu households had higher vaccination coverage than Muslim households, although the investigators suggested that this was more a result of higher literacy rate and education than religion alone. Incidentally, no gender-based inequities were observed.

An intervention trial [48] compared health indicators in 105 villages in Uttar Pradesh, cluster-randomized to receive either enhanced awareness through public meetings or no intervention. The investigators included some data on vaccination status by caste. They noted that the vaccination rate (defined as receipt of one or more childhood vaccines) in the control group (that did not receive any intervention) was comparable (46-47%) among families belonging to scheduled caste as well as mid to high caste. Although this design is inappropriate to evaluate the impact of caste; the vaccination rates by caste were similar in the control group population at baseline as well as after the one-year trial; whereas it had increased significantly in the intervention group.

A group of scientists in Tamil Nadu compared vaccination coverage rates determined by the standard 30-cluster survey method used by the Government of

India and a Purposive method [49]. The basis for this comparison was the difference in the technique used to obtain the sample in these methods. Sampling with the 30-cluster method starts close to the village centre and thereby is likely to exclude the scheduled caste/tribe and other backward class families living at the periphery or in pockets. The Purposive method reportedly ensures less exclusion. Although the data showed no significant coverage differences with the two methods, 30-cluster sampling method gave slightly higher coverage rates; there was nearly difference 7% for measles vaccine. The authors suggested that the conventional 30-cluster sampling method may yield falsely higher vaccination coverage rates on account of exclusion of socially deprived segments of the population.

Effect of Access to Health-care Services and other Infrastructure

The ICMR survey (1999) [3] reported complete vaccination coverage in only 19% infants living in small (population <500) villages located more than 5 km away from health centers. In contrast, villages located within 1 km of a health-care center had 56.9% coverage. However, some villages that were relatively near health centers also had lower vaccination.

In a study in Udaipur district in Rajasthan [45], there was a relationship between the vaccination status of 2365 children (< 5 years old) and the distance of their household from the nearest primary health-care centre. Complete vaccination rate was 55% for households <1 km away, 47% for distances 1-2 km, 32% for distance 2-7 km; and 30% for >7 km from health centers. Incidentally less wealthy families lived farther away from primary health-care facilities than more wealthy counterparts.

Almost two decades back, a survey was undertaken in Lucknow's slum areas [50]. At that time, there were 110 slums accounting for about 13% of the city's population. Among these, 40% slums with about 47% of the slum population were covered by the Urban Basic Services (UBS) program launched in 1986. The survey compared the vaccination status of children living in slums with and without UBS coverage approximately three years after the program inception. Standard 30-cluster sampling with 7 eligible infants (12-23 months) each was employed. The proportion of fully vaccinated children was 16.2% in UBS slums compared to 10.9% in non-UBS slums. The respective proportions of partially-vaccinated infants were 46.2% and 51.5%. There was no difference in the proportion of non-vaccinated infants (37.6% each). The drop-out rate between the first and second doses of DPT vaccine was comparable in the two types of slums; however the drop-out rate between the second and third doses of DPT was somewhat higher in non-UBS slums. The measles vaccine coverage in UBS slums was 18.6% compared to 11.9% in non-UBS slums.

Another group analyzed vaccination status of 4844, 0-4 year old children and categorised it by their usage of public or private care sector health-care facilities for outpatient curative services in the preceding fortnight [51]. They included data for only one child per household and controlled for multiple factors including demographics, household socioeconomic status, and state of residence. The likelihood of vaccination was not different among those who used private or public sector health-care services except for measles vaccine. They also categorised the data of those who accessed private sector services by reasons of proximity or reasons of quality; the latter had a higher proportion of vaccinated infants.

A group of investigators [52] examined NFHS-1 data and observed a significantly higher rate of complete vaccination among infants whose mothers had received antenatal care in the first trimester compared to those who did not (62.4% *vs* 31.7%).

A vaccine coverage survey in Assam [26] reported a positive relationship with access to health-care facilities (64.5% complete vaccination compared to 57.4% among those with no access). The data also suggested better vaccination status among those residing within 2 km of health centers.

A door-to-door household comparative survey was carried out in 1993 in one rural ICDS (Integrated Child Development Scheme) block and five non-ICDS rural areas in Madhya Pradesh state [53]. Vaccination data of 709 and 500 children (1-2 years) respectively was collected. The proportion of vaccinated infants was lower in the ICDS areas than non-ICDS areas for all vaccines; 80.2% *vs* 88.8% for BCG, 79.5% *vs* 94.4% for three doses of DPT, 88.0% *vs* 95.3% for three doses of OPV, and 45.7% *vs* 62.0% for measles vaccine. These differences are significant especially as nutritional status of children in both areas was comparable.

A hospital-based study was conducted in a tertiary-care teaching hospital in Delhi [54]; wherein the vaccination status of 325 consecutive admitted children in the age range 1-5 years was evaluated. Maternal report was the primary method of obtaining vaccination information; additional examination of vaccination cards was done where possible. Less than one-fifth children were completely vaccinated; nearly half were partially vaccinated and one-third had not received any vaccine. The majority of fully vaccinated children had vaccination cards that could be cross-checked; whereas cards were available in only a minority of the other children. Most of the children who were not fully vaccinated had received multiple doses of OPV during National Immunization days. The authors presented vaccination data by gender, religion, parental education, and place of delivery; however as this was a hospital-based study and the demographic profile of admitted patients was not described, these variables have not been examined further in this review.

Sahu *et al.* [55] examined NFHS-2 data to estimate the impact of individual and community characteristics such as age, gender and birth order of infants; maternal age, prenatal care, post-natal care, parental education, institutional delivery, and access to basic facilities such as health centers, roads and IEC (information, education and communication) activities. They conducted a two-step analysis to evaluate the vaccination status based on different subgroups and individual as well as community characteristics. The data showed that infants living in communities with all-weather roads, public-sector health facilities, and exposed to IEC activities had higher complete vaccination coverage compared to their counterparts.

Effect of Pulse Polio Immunization Program (PPIP)

A group of investigators studied the effect of the pulse polio immunization program on routine immunization of infants (12-35 months) residing in rural areas of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh [56]. They evaluated vaccination coverage before and after the initial years of the pulse polio immunization program (PPIP) comparing NFHS-1 (1992-93) and NFHS-2 (1998-99) data. Four outcomes were examined *viz.*. receipt of first dose of OPV, 3 doses of OPV, at least one dose of any of the non-polio EPI vaccines; and complete immunization. They reported that the proportion of children who received the first dose of OPV was 48.1% (95% CI 45.9-50.3%) in 1993 which increased to 72.6% (95% CI 70.6-74.5%) in 1999. Since the coverage with first dose of DPT during the two periods was not very different; 48.0% (95% CI 45.9%-50.2%) and 49.9% (95% CI 48.0-51.9%) respectively; the increase in OPV coverage could be attributed to the PPIP. Likewise, there was no significant change in coverage with at least one dose of non-polio EPI vaccines; 50.9% (95% CI 48.8-53.1%) and 56.4% (95% CI 54.4-58.4%) in 1993 and 1999 respectively. The complete immunization coverage in the respective time periods was also similar 17.7% (95% CI 16.2-19.3%) in 1993 and 18.5% (17.2-19.8%) in 1999. Thus there was a disproportionate increase in OPV coverage between 1992-93 and 1998-99. The data also showed that although wealth-based inequity declined for polio vaccination, it increased for other vaccines. Some reduction in caste- based inequities were observed, but there was no impact on religion- or residence-based inequities.

The authors offered two possible explanations *viz.* that PPIP enhanced knowledge and awareness of polio vaccination but had no effect on the other vaccination; or the potential increase in routine vaccination (manifested by increased OPV coverage) was hindered by the PPIP. It is possible that neither of these extreme positions is absolutely correct; however the significant conclusion was that although the pulse polio program resulted in decline in polio cases, it did not translate into opportunities to increase and sustain routine immunization.

Maternal Age at Childbirth

The latest UNICEF coverage evaluation survey [13] reported infant vaccination in relation to maternal age; complete vaccination was 59.8% in infants with mothers 15-19 years, 65.7% with 20-24 year old mothers, 59.5% for maternal age 25-34 years, 45.5% for 35-44 years, and 56.6% for >44 years. The respective non-vaccination rates were 6.9%, 5.8%, 7.7%, 17.3%, and 13.8%. The UNICEF 2005 survey [12] reported that among infants with mothers <25 years of age, complete vaccination was observed in 56.9%; among mothers 25-34 years old, it was 54.5%; however infants of mothers >35 years had 37.8% complete vaccination rate.

One research study [57] examined NFHS-3 data and reported complete vaccination in 41% infants born to adolescent mothers (15-19 years). Within this group of young mothers, relatively younger maternal age (less than 18 years) was associated with lower complete vaccination rate (39.8%) compared to 43.6% among infants of mothers 18-19 years old (OR 1.2, 95 CI 0.94-1.52). Female infants had lower complete vaccination than males (39.6% *vs* 42.3%). Infants of adolescent mothers living in villages had less complete vaccination (39.1%) compared to those in urban areas (49.9%); OR 0.83, 95% CI 0.62-1.11. Maternal literacy had a direct relationship with infant vaccination; complete coverage was 24.8% among infants of illiterate mothers, 47.6% with education below primary level (OR 2.48, 95% CI 1.6-3.84); 49.2% for primary level (OR 2.3, 95% CI 1.65-3.21); 60.5% for middle level (OR 3.24, 95% CI 2.20- 4.75), and 62.7% for high school level education (OR 2.52, 95% CI 1.57-4.05). Paternal education also had an impact; infants of only 31.8% of literate fathers were completely immunized compared to 36.2% with below primary level education (OR 0.94, 95% CI 0.58-

1.52); 43.7% with primary education (OR 1.21, 95% CI 0.84-1.73); 38.7% with middle level (OR 1.01, 95% CI 0.69-1.48); and 53.4% among those with high school level education (OR 1.18, 95% CI 0.79-1.76). There were marginal differences based on religion; 40.8% infants in Hindu households compared to 43.0% in Muslim families were fully vaccinated. Among general caste families, complete vaccination coverage was noted in 48.9% infants, compared to 39.0% among scheduled caste, 33.4% among scheduled tribe, and 38.9% among other backward classes; however these differences were not statistically significant. Infants of mothers with no exposure to media had lower (32.8%) vaccination coverage compared to 45.2% among mothers with media exposure (OR 1.15, 95% CI 0.84-1.57). There was a direct relationship between wealth quintile and complete vaccination status; the coverage was 29.9% among poorest (OR 1.17, 95% CI 0.79-1.72); 33.5% among poor (OR 1.63, 95% CI 1.09-2.45); 47.1% among middle wealth group, 50.1% among rich (OR 1.68, 95% CI 1.06-2.64) and 64.7% among wealthiest group (OR 3.19, 95% CI 1.74-5.82). Infants living in nuclear families had lower vaccination coverage than joint families (38.7% *vs* 44.5%; OR 0.99, 95% CI 0.76-1.28). Infants with higher birth order had lower vaccination coverage. One significant finding was that unwanted babies of the adolescent mothers had very low vaccination coverage compared to wanted babies (19.1% *vs* 42.3%; OR 0.36, 95% CI 0.18-0.70). Yet another interesting finding was that the likelihood of complete vaccination varied by region; it was 31.9% in northern states, 23.6% in central states, 49.8% in eastern states, 36.4% in north-eastern states, 50.7% in western states and 51.8% in southern states.

Household Size

A survey in Goa [29] observed that the proportion of fully vaccinated infants was related to the size of the household; 98.4% infants in households with less than 3 members were fully vaccinated, compared to 85.4% with household size 3-6; and 68.0% with household size greater than 6.

DISCUSSION

This systematic review has examined the inequities in childhood vaccination by individual infant factors (gender, birth order), individual family characteristics (area of residence, maternal and paternal education status, household economic status, maternal access to health-care), social characteristics (religion, caste), community characteristics (access to health-care and other infrastructure), and state-level differences. The review process had several strengths including a systematic approach, detailed literature search from multiple sources, inclusion of publications that actually measured vaccination coverage directly, and consideration of all types of study design.

Certain limitations must also be recognized *viz.* the inability to access literature databases such as EMBASE, and administrative databases of institutions and organizations at the state and national level. No effort was made to pool data through meta-analysis, as the objective was to explore rather than quantify factors associated with inequitable vaccination. Despite these limitations, the review has uncovered several important findings *viz.* inequity in childhood vaccination among girls, higher birth order infants, rural areas and urban slums compared to urban areas, uneducated/illiterate parents, and poorer socio-economic strata families. Inequity based on caste and religion has also been highlighted. An indirect negative impact of the pulse polio immunization program on routine childhood vaccination has been described; but not fully substantiated.

It can be argued that most of the inequities uncovered in this systematic review are intuitively obvious from experience over several decades. For example, female gender, poverty, illiteracy etc are the ‘usual’ risk factors for not only health-related outcomes, but all other human development outcomes. The issue is what can be done to redress the problems identified. The three NFHS surveys over a decade and half have consistently reported more-or-less the same inequities and if anything, a worsening trend over time. However, the knowledge has not been translated to action(s) to address the problem. Therefore, it is entirely possible that subsequent surveys will also show similar findings unless something is done urgently. An obvious proposal would be targeted campaigns to identify and vaccinate the groups of infants at highest risk of being unimmunized or incompletely vaccinated. However, as discussed below, this may not be the right approach.

This review also shows that some states are “better” than others in terms of vaccination performance; it also shows that certain sections of the population have better coverage (for example wealthiest segment, people with highest level of education etc). However this should not distract us from the realization that the ‘better’ and even the ‘best’ are not good enough. For example, the complete vaccination coverage in the ‘best’ Indian state approaches only 80%; while this is certainly better than other states, it is inadequate from the perspective of disease control/eradication. Similarly, higher level of maternal education is associated with higher infant vaccination. However, the NFHS-3 data showed that even among mothers with the highest educational standard (12 or more completed years of education), complete vaccination coverage was only 75%. Likewise, complete vaccination coverage in the wealthiest quintile was also only around 75%. Such observations argue for strategies to target vaccination inadequacies rather than inequities alone.

It is also important to note that the inequities and inadequacies observed in the NFHS surveys are not restricted to vaccination alone but also other child health issues like nutritional status, respiratory illness, diarrheal disease, access to health-care services, appropriate management of common childhood diseases etc [4-6, 58,59]. This suggests that merely tackling the 'vaccination deficit' to achieve 'targets' could be helpful in the short-term but most likely fail in the long-term. However vaccination is somewhat different from other health-care interventions in the sense that it is administered to otherwise healthy infants; individual choice (to vaccinate or not vaccinate a particular infant) has an impact on the community; and successful vaccination requires families to be proactive rather than reactive. Therefore childhood vaccination requires higher levels of motivation amongst families and communities; this can only be achieved through empowerment especially with knowledge and education.

Based on these observations and perceptions, findings of this review call for action to strengthen the routine immunization program in a robust manner, rather than execute knee-jerk reactions to address inequities. A previous systematic review [60] outlined evidence-based options to improve routine childhood immunization, by increasing acceptability amongst families and making vaccination a more pleasant and convenient experience for infants and families. Another review [61] outlined approaches to strengthen the overall routine immunization system, focusing on concrete outcomes (targets) such as reduction in disease burden rather than vaccination coverage (which is only a surrogate marker).

It should also be noted that childhood vaccination is only one component of child health and overall societal health. Favourable health outcomes in the country can only be expected by overall strengthening of health-care systems and empowerment of people in general. In other words, a dual approach has to be planned; *viz.* a short-term plan to reduce vaccination inadequacy and inequity; and a long-term strategy to strengthen the overall health-care system.

This systematic review shows that while the NFHS series comprise the most robust data on absolute inequities, the lack of statistical treatment and absence of analysis of risk factors controlling for complementary and confounding factors, make the interpretation of findings somewhat difficult. For example, there are numerous factors linked with inequity; but in the absence of calculation of adjusted odds ratio or relative risk, the precise significance of the observation remains unclear. It also does not examine the combined effect of multiple risk factors in a given infant. A significant observation in this systematic review is that there are small data sets independent of the NFHS series that have addressed these issues. Although these are not representative of the country at large, viewed in conjunction with the NFHS data, they provide directions for action. The other finding in this review is the wealth of secondary analysis of the NFHS data (undertaken almost exclusively by researchers abroad) that permit analysis of the NFHS data in perspective.

Certain other important observations in this systematic review must also be highlighted. There is clear disparity between nation-wide ICMR survey data during 1999 [3] and the NFHS-2 survey [5] data over 1998-99. Given that both surveys used robust sampling strategies to ensure appropriate population representations, it is unclear why the results are vastly different. The ICMR survey showed higher total vaccination coverage and also better performance across all factors evaluated. It even failed to identify significant gender-based imbalances. Exploration of the reasons behind these differences was outside the scope of this review. However this emphasizes that careful appraisal of methodological design (used for collection and calculation of vaccination data) is critical to a proper understanding of the situation.

The data from the 2009-10 UNICEF survey [13] are also a little surprising as it reports nearly 20% higher complete vaccination rate compared to the NFHS-3 survey [6]. This could represent tremendous progress in vaccination coverage over the four year period between the two surveys. On the other hand, it may reflect methodological differences and/or inconsistencies; in which case the validity of the data may be questionable. This is especially relevant because the 2005 coverage survey [12] also reported a significantly higher complete vaccination rate compared to the NFHS survey at around the same time period.

Another important observation from the NFHS-3 data is that coverage for individual vaccines (BCG, DPT, OPV) is much higher than the proportion of "fully vaccinated" infants; suggesting significant decline in coverage for each subsequent dose of DPT/OPV and between the third dose of DPT/OPV and measles vaccine; suggesting that coverage rates decline as infants grow older. Another interesting observation is that

KEY MESSAGES

- There are limited nation-wide data exploring inequity in childhood immunization in India; among these the three National Family Health Surveys are methodologically the most robust. Data from an apparently methodologically robust ICMR survey in 1999 was not corroborated by contemporary NFHS survey data.
- Data from smaller, focused surveys often yielded conclusions similar to the NFHS data; however in some cases there were clear differences in the conclusions.
- There is a high level of disparity in vaccination coverage in different states. The traditionally poor preforming states have greater inequities; however there is significant inequity even among better performing states.
- There are considerable inequities in childhood vaccination by various individual (gender, birth order), family (area of residence, wealth, parental education), social (religion, caste), and societal (access to health-care, community literacy level) characteristics.
- In general, girls fare worse than boys; there is an almost 5% relative difference between boys and girls. Higher birth order infants have lower vaccination rate; the precise reasons for this have not been elucidated.
- Urban infants have higher coverage than rural infants and those living in urban slums. There is an almost direct relationship between household wealth and vaccination rates.
- The vaccination rates are lower among infants with mothers having no or low literacy, and families with insufficient empowerment of women. Paternal literacy has an inconsistent positive relationship with infant vaccination.
- There is a relationship between religion and caste, and childhood vaccination; however data are limited to determine whether these are independent influences or reflections of other inequities.
- Access to health services and other infrastructure, is associated with better vaccination coverage of infants.
- The precise impact of specific risk factors operating singly or in combination cannot be calculated from this systematic review; however it provides directions for targeting the most vulnerable sections of the population.

although DPT and OPV doses are administered at the same age (and therefore ideally at the same vaccination session), there is a consistent difference between the coverage for the two vaccines. This raises three possibilities *viz.* either parents are selectively opting for oral vaccine, or personnel administering vaccines are more conservative with the injectable vaccine; or some of the OPV doses reported by mothers could be related to the numerous pulse polio vaccination rounds and not the primary immunization series. A fourth possibility that mothers somehow forgot the DPT doses but remembered OPV doses is unlikely given that vaccines administered by injection (especially if associated with high frequency of local and/or systemic side effects), are expected to be better remembered.

The declining vaccination coverage of higher birth order infants needs further exploration. It is often explained away stating that families with more children become less vigilant about vaccination. However intuitively speaking, the opposite is expected to be more likely, as experience with caring for first-born infants would better familiarize mothers as well as other family members with the vaccination schedule. A possible reason that has not been explored at all is whether the absence of occurrence of vaccine preventable diseases in first born infants and the community, fosters complacency (or worse resistance) towards vaccination.

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