Vaccine xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998–2008

Mark Rohit Francis [a], Hanna Nohynek [b], Heidi Larson [c], Vinohar Balraj [d], Venkata Raghava Mohan [e], Gagandeep Kang [f], J. Pekka Nuorti [a,b,*]

[a] Department of Epidemiology, Health Sciences, Faculty of Social Sciences, University of Tampere, Tampere, Finland
[b] Department of Health Security, National Institute for Health and Welfare (THL), Helsinki, Finland
[c] Department of Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, UK
[d] Society for Applied Studies, Vellore, Tamil Nadu, India
[e] Department of Community Health, Christian Medical College, Vellore, Tamil Nadu, India
[f] Division of Gastrointestinal Sciences, Christian Medical College, Vellore, Tamil Nadu, India

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Socioeconomic factors
Partial or non-vaccination
Routine immunization
EPI

ABSTRACT

Background: Despite almost three decades of the Universal Immunization Program in India, a little more than half the children aged 12–23 months receive the full schedule of routine vaccinations. We examined socio-demographic factors associated with partial-vaccination and non-vaccination and the reasons for non-vaccination among Indian children during 1998 and 2008.

Methods: Data from three consecutive, nationally-representative, District Level Household and Facility Surveys (1998–99, 2002–04 and 2007–08) were pooled. Multinomial logistic regression was used to identify individual and household level socio-demographic variables associated with the child's vaccination status. The mother's reported reasons for non-vaccination were analyzed qualitatively, adapting from a previously published framework.

Results: The pooled dataset contained information on 178,473 children 12–23 months of age; 53%, 32% and 15% were fully vaccinated, partially vaccinated and unvaccinated respectively. Compared with the 1998–1999 survey, children in the 2007–2008 survey were less likely to be unvaccinated (Adjusted Prevalence Odds Ratio (aPOR): 0.92, 95%CI = 0.86–0.98) but more likely to be partially vaccinated (aPOR: 1.58, 95%CI = 1.52–1.65). Vaccination status was inversely associated with female gender, Muslim religion, lower caste, urban residence and maternal characteristics such as lower educational attainment, non-institutional delivery, fewer antenatal care visits and non-receipt of maternal tetanus vaccination. The mother's reported reasons for non-vaccination indicated gaps in awareness, acceptance and affordability (financial and non-financial costs) related to routine vaccinations.

Conclusions: Persisting socio-demographic disparities related to partial-vaccination and non-vaccination were associated with important childhood, maternal and household characteristics. Further research investigating the causal pathways through which maternal and social characteristics influence decision-making for childhood vaccinations is needed to improve uptake of routine vaccination in India. Also, efforts to increase uptake should address parental fears related to vaccination to improve trust in government health services as part of ongoing social mobilization and communication strategies.

1. Introduction

Globally about one-third of the annual vaccine preventable child deaths or 500,000 deaths occur in India [1,2]. While most vaccine preventable deaths in India are due to pneumonia and diarrhea, complete immunization with existing routine vaccines against tuberculosis, diphtheria, pertussis and tetanus, polio,

Abbreviations: UIP, Universal Immunization Program; EPI, Expanded Program on Immunization; DLHS, District Level Household and Facility Survey; BCG, Bacillus Calmette-Guerin; DPT, Diphtheria-Pertussis-Tetanus; OPV, Oral Polio Vaccine; NFHS, National Family Health Survey; PSU, Primary Sampling Unit; ANM, Auxiliary Nurse Midwife.

* Corresponding author at: Department of Epidemiology, Health Sciences, Faculty of Social Sciences, University of Tampere, 33520 Tampere, Finland.
E-mail address: Pekka.Nuorti@uta.fi (J.P. Nuorti).

http://dx.doi.org/10.1016/j.vaccine.2017.08.026
0264-410X/

measles, hepatitis B and *H. influenzae* type b are essential to avert the associated mortality, morbidity and to prevent future outbreaks of these vaccine preventable diseases [3]. However, despite almost three decades of the UIP, the proportion of children aged 12–23 months receiving the full schedule of vaccinations in India is around 61% and for third dose DPT (DPT3) coverage is 72%, still below the global average of 86% [4]. The persisting low routine immunization coverage implies that one in three children born every year still do not receive complete protection against the diseases currently covered by the UIP, placing them at the highest risk of mortality and morbidity [2,5].

India's slow progress to achieving universal immunization for all children has generally been attributed to its sheer population size, high growth rate, geographic and cultural diversity and limited healthcare spending [6,7]. However, large inter-state and inter-district disparities in immunization coverage have helped uncover important supply and demand-side factors associated with uptake of routine vaccinations [7–9]. Supply-side factors generally include a lack of trained personnel to manage and deliver immunization services, poor relationship between health care workers and mothers, inconvenient timing or location of immunization services and even vaccine stock outs [6,8,10]. Demand-side factors associated with routine vaccination uptake however are complex and often multi-faceted. Previous research from India tends to highlight socio-demographic characteristics associated with uptake such as child's gender, order of birth, place of delivery, maternal age at childbirth, parental education, caste and religious preference, household wealth and location (urban or rural), [6–8,11,12]. Of late, non-socio-demographic demand-side issues such as awareness regarding the need for and timing of routine childhood vaccinations, fears regarding some or all routine vaccines and parental beliefs regarding false contraindications to routine vaccinations have been reported as reasons linked to partial-vaccination and non-vaccination of Indian children [4,12,13]. As, the Indian Government aims to boost full immunization coverage of UIP vaccines to 90% through the Mission Indradhanush initiative by 2020, it is important to track the various socio-demographic and non-socio-demographic factors influencing suboptimal vaccination over the years to identify key areas of intervention and further research.

We used pre-existing, nationally-representative datasets from three rounds of India's District Level Household and facility Survey's (DLHS) conducted from 1998 to 2008 to: (1) examine the socio-demographic factors associated with vaccination status of children aged 12–23 months at the time of survey (focusing on partial-vaccination and non-vaccination) and (2) categorize the reasons reported for non-vaccination by adapting the previously published "5A's Taxonomy for Determinants of Vaccine Uptake" [14], intended for non-socio-demographic factors.

2. Methods

2.1. Data source, sampling and survey questionnaire

The DLHS cross-sectional surveys are conducted periodically to monitor and assess reproductive and child health program indicators in every district of India. To date, four rounds of the DLHS have been completed (DLHS-1 in 1998–99, DLHS-2 in 2002–04, DLHS-3 in 2007–08 & DLHS-4 in 2012–13). Data from DLHS-4 were excluded because the survey was not nationally representative (DLHS-4 covered 336 of 640 Indian districts). Each DLHS round employed a similar systematic, multi-stage stratified sampling scheme. Additional detail on the survey design and calculation of sampling weights are available in the Appendix and elsewhere [15–18].

Interviews with currently married (or ever married) women and with any adult family member (aged 18 years and above) collected information for the "women's questionnaire" and "household questionnaire" respectively. We used information from the "women's questionnaire" containing relevant information on socio-demographic characteristics and childhood immunization information. The type and number of questions providing information on child, maternal and household characteristics and immunization histories were generally similar for the DLHS surveys, however, there were more questions about child and maternal health from DLHS-1 to DLHS-4 [19] (See Appendix for more details on questionnaire). In the DLHS, immunization histories for the last two surviving children were obtained from the vaccination card of the children. If the vaccination card was not available immunization data were based on maternal recall. The study sample comprised the most recently born children aged 12–23 months at the time of survey to limit the influence of poor maternal recall on immunization histories of older children. Also, for consistency and pooling we further restricted analysis to children of mothers who were currently married (*i.e.* ever-married mothers were excluded as they were only interviewed in DLHS-3) and aged 15–44 years at the time of survey (*i.e.* mothers aged >44 years from DLHS-3 were excluded).

2.2. Socio-demographic variables

Individual, household and regional characteristics having a previously reported association with children's vaccination status and with complete data available in the survey datasets were chosen for analysis. Individual characteristics included child-specific characteristics such as gender and age in months and maternal characteristics such as mother's age at childbirth, educational attainment, antenatal participation, place of delivery and maternal tetanus vaccination status [20–23]. In addition, caste and religious preference of the head of household were selected [22,24]. Household characteristics included urban or rural location and in the absence of a readily available wealth index measure (for DLHS-1), type of dwelling (Mud, semi-cemented or cemented) was used as a proxy measure of household wealth. And, geographical region of residence in India categorized as North, Central, North-East, West and South was used as the regional indicator for adjustment [7]. Further details on the variables are provided in the Appendix.

2.3. Outcome variable

The current Indian UIP schedule recommends one dose of BCG vaccine at birth (or as soon as possible), three doses of DPT, OPV and Hepatitis B (added in 2007) or pentavalent vaccine (available in some Indian states since 2011) provided at 6, 10 and 14 weeks of age and one dose of measles vaccine at 9 months of age. The main outcome of study was the vaccination status of children 12–23 months of age, defined using EPI recommendations which were in use during the surveys as follows [22,25]:

(1) Fully vaccinated – Children who received one dose of BCG, three doses of DPT, three doses of OPV (excluding the zero dose) and one dose of measles vaccine by 12 months of age.
(2) Partially vaccinated – Children who received at least one but not all the recommended vaccines by 12 months of age.
(3) Unvaccinated – Children who did not receive any of the recommended vaccines by 12 months of age.

Please cite this article in press as: Francis MR et al. Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998–2008. Vaccine (2017), http://dx.doi.org/10.1016/j.vaccine.2017.08.026

2.4. Statistical analysis

Data from the three DLHS surveys were pooled to examine the socio-demographic factors associated with children's vaccination status over the ten-year period covered by the surveys. Similar pooling of data to assess trends and determine predictors of immunization coverage have been reported using the National Family Health Survey (India's Demographic & Health Survey) datasets [26]. Because of the complex, stratified sampling design, appropriate weighting of coverage proportions and regression estimates was done using the supplied national sampling weights for each survey. Univariate regression analysis was performed to examine associations between the socio-demographic variables and children's vaccination status for all surveys combined (see Appendix for technical details). All the socio-demographic variables which had a significant univariate association with vaccination status at the $p \leq 0.05$ level were included in the multivariate regression analysis to examine factors associated with partial-vaccination and non-vaccination compared with full vaccination for children aged 12–23 months as previously described [22]. Also, since the outcome of children's vaccination status had three levels, a pooled multinomial logistic regression adjusted for age of the child, type of dwelling, survey period and geographic region. Results of the multivariate regression modeling are presented as adjusted Prevalence Odds Ratio's (aPOR's) with 95% Confidence Interval's (CIs). The relative importance of each socio-demographic variable in the multivariate regression model was assessed using Wald Test *p*-values. We also performed secondary analyses restricting the analytical sample to the partially vaccinated children to explore differences in the socio-demographic factors associated with vaccination status based on whether children received "very few" vaccines (1–2 doses), "some" vaccines (3–5 doses) or "almost all" vaccines (6–7 doses). The survey analyses were performed using the "*svy*" package in STATA version 12 and figures made using Excel 2013.

Table 1
Definitions and contributing factors of the "5As Taxonomy for Determinants of Vaccine Uptake" [14].

Root causes	Definition
Access	The ability of individuals to be reached by, or to reach, recommended vaccines
Affordability	The ability of individuals to afford vaccination, both in terms of financial and non-financial costs (e.g. time)
Awareness	The degree to which individuals have knowledge of the need for, and availability of, recommended vaccines and their objective benefits and risks
Acceptance	The degree to which individuals accept, question or refuse vaccination
Activation	The degree to which individuals are nudged towards vaccination uptake

2.5. Categorization of reasons for non-vaccination

In the DLHS "women's questionnaire", mothers whose children had not received even a single dose of the recommended UIP vaccines were asked to choose either one important reason (DLHS-1 & DLHS-2) or one or more reasons (DLHS-3) from a list of predetermined responses to the question "Why was your child not given any vaccination?". To organize the reported reasons for non-vaccination we used a semi-qualitative, framework-based methodology to categorize individual responses (separately for each survey) using the recently published "5A's Taxonomy for Determinants of Vaccine Uptake" to help identify the important underlying reasons for non-vaccination among Indian children [14]. The working definitions for each of the root causes in the 5As taxonomy are presented in Table 1.

3. Results

There were a total of 58,777 (31% of all surveyed children), 58,416 (30%), 61,280 (28%) and 178,473 (30%) eligible children aged 12–23 months in the DLHS-1, DLHS-2, DLHS-3 and the combined surveys respectively. Of these children, 74% lived in rural locations and 38% in mud households. Fifty-three percent of the children were male and 78% of the children were Hindu (Supplemental Table 1). Also, 50% of the children had mothers without any formal schooling and 59% of mothers had non-institutional deliveries.

Coverage of important UIP vaccine doses and children's vaccination status for the individual and combined surveys are presented in Table 2. Of the eligible children, 32% did not have a vaccination card and 30% reportedly had vaccination cards which could not be presented at the time of survey. Overall, coverage of BCG vaccination was highest (81%) and coverage of the third dose DPT (DPT3) vaccine was 62%, similar to third dose OPV (68%) and first dose measles

Table 2
Vaccination proportions for Indian children aged 12–23 months, DLHS1-3.

Category	Weighted percentages (95% CI)					
	DLHS-1 (1998–99)	DLHS-2 (2002–04)	DLHS-3 (2007–08)	Combined surveys (DLHS 1–3)	Relative change (%)*	P-value **
Vaccination card						
No	35.1 (34.5–35.6)	39.6 (38.9–40.5)	25.1 (24.6–25.7)	31.5 (31.1–31.9)	−28.4	<0.001
Yes (not seen)	30.8 (30.3–31.3)	29.0 (28.4–29.5)	31.0 (30.6–31.4)	30.4 (30.1–30.7)	0.6	
Yes (seen)	34.1 (33.6–34.7)	31.4 (30.7–32.1)	43.9 (43.3–44.4)	38.1 (31.1–31.9)	28.7	
BCG	73.9 (73.4–74.4)	75.4 (74.7–76.1)	87.4 (87.0–87.8)	80.7 (80.4–81.0)	18.3	<0.001
DPT3	65.9 (65.3–66.4)	58.6 (57.8–59.3)	60.8 (60.3–61.4)	62.2 (61.8–62.6)	−7.0	<0.001
OPV3	67.9 (67.3–68.4)	59.4 (58.6–60.2)	71.2 (71.4–72.4)	67.5 (67.1–67.9)	4.9	<0.001
Measles	60.0 (59.3–60.5)	56.8 (56.0–57.6)	73.9 (73.4–74.4)	65.7 (65.2–66.1)	23.2	<0.001
Fully vaccinated	54.3 (53.7–54.9)	47.9 (47.1–48.7)	56.0 (55.5–56.6)	53.4 (52.9–53.8)	3.1	
Partially vaccinated	27.4 (26.9–27.9)	32.1 (31.5–32.8)	34.6 (34.2–35.1)	32.1 (31.7–32.4)	26.3	
Very few (1 –2)	18.3 (17.5–19.2)	17.5 (16.1–18.8)	11.4 (10.9–11.8)	14.6 (14.0–15.2)	−37.7	<0.001
Some (3 –5)	32.8 (31.7–33.9)	35.5 (34.4–36.6)	35.8 (34.9–36.7)	35.0 (34.5–35.6)	9.1	
Almost all (6 –7)	48.9 (47.9–49.8)	47.0 (45.3–48.8)	52.8 (51.9–53.8)	50.4 (49.5–51.2)	7.9	
Unvaccinated	18.3 (17.9–18.8)	20.0 (19.4–20.6)	9.4 (9.0–9.7)	14.5 (14.3–14.9)	−48.6	

N = 58 777, 58 416 & 61 279 for DLHS-1, DLHS-2 & DLHS-3 respectively.
BCG: Bacillus Calmette – Guerin, DPT: Diptheria-Pertussis-Tetanus, OPV: Oral Polio Vaccine.
* Relative change calculated as ((DLHS1%/DLHS3%) – 1).
** P-value of trend from Chi-square using Rao-Scott design adjustment.

Please cite this article in press as: Francis MR et al. Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998–2008. Vaccine (2017), http://dx.doi.org/10.1016/j.vaccine.2017.08.026

(66%) vaccines. Coverage of BCG and measles vaccination increased from 74% to 87% and 60% to 74% respectively from 1998–1999 (DLHS-1) to 2007–2008 (DLHS-3). However, DPT3 coverage decreased from 66% to 61% for the same period. Fifty-three percent of the eligible children were fully vaccinated, with 32% and 15% partially vaccinated and unvaccinated respectively. The proportion of unvaccinated children was reduced from 18% to 9% and the proportion of partially vaccinated children increased from 27% to 35% from the 1998–1999 (DLHS-1) period to the 2007–2008 (DLHS-3) period.

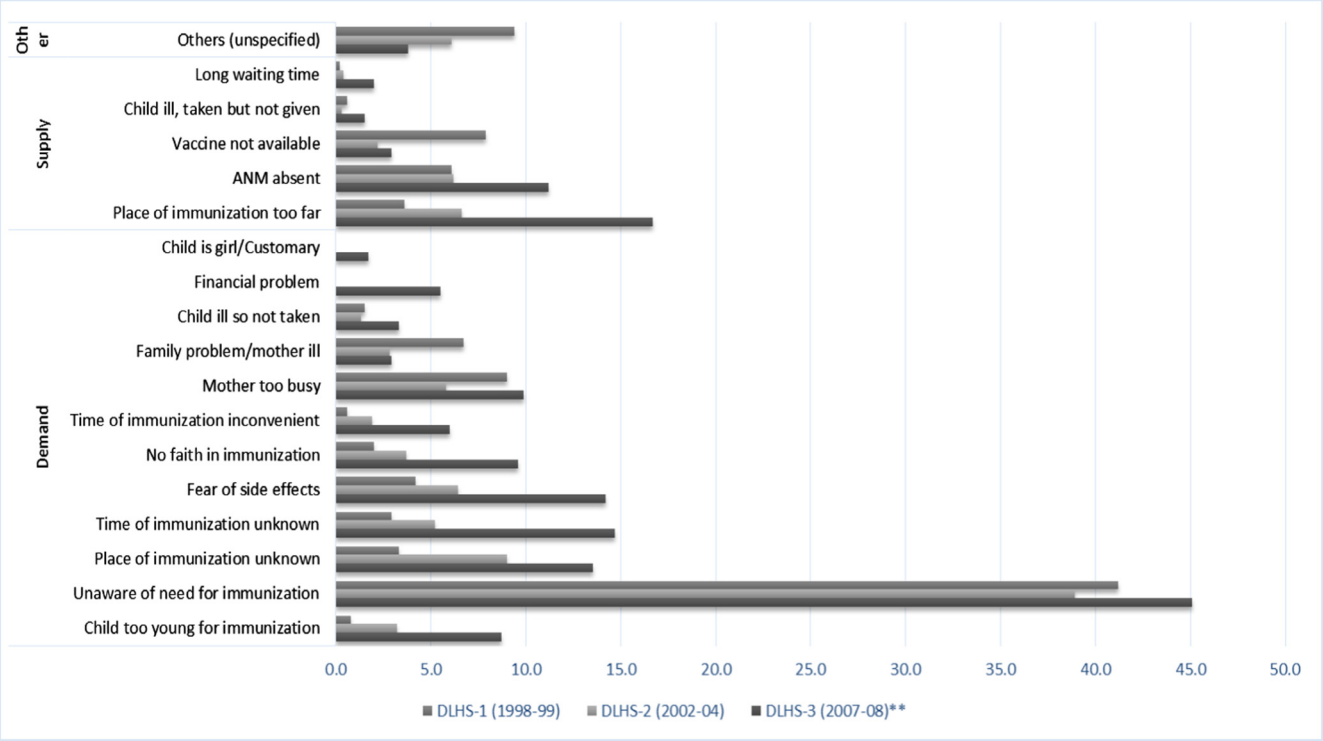
Results of the pooled multivariate analysis are presented in Table 3. Children in the 2007–2008 (DLHS-3) period were less likely to be unvaccinated (aPOR: 0.92, 95%CI = 0.86–0.98) and more likely to be partially vaccinated compared to the 1998–1999 period (DLHS-1) (aPOR: 1.58, 95% CI = 1.52–1.65). After adjusting for age of the child, type of dwelling, survey period and geographic region, female children were more likely to be unvaccinated than males (aPOR: 1.16, 95%CI = 1.10–1.21). Children living in urban households (compared with rural households) were more likely to be unvaccinated (aPOR: 1.37, 95% CI = 1.26–1.49). Compared to Hindu children, Muslim children were more likely to be unvaccinated (aPOR: 2.03, 95% CI = 1.89–2.18) and partially vaccinated (aPOR: 1.44, 95%CI = 1.37–1.51). And, relative to children belonging to the general class, those belonging to scheduled caste and other backward classes were more likely to be unvaccinated. Lower maternal education, fewer antenatal care visits, non-institutional delivery, non-receipt of maternal tetanus vaccination and non-retention of children's vaccination cards were similarly associated with increased odds of children being unvaccinated and partially

Table 3
Results of multivariate regression modeling for pooled DLHS datasets.

Covariates	Weighted proportions (95%CI)*			Adjusted prevalence odds ratio (95% CI)**	
	Fully-vaccinated	Partially-vaccinated	Unvaccinated	Unvaccinated versus full vaccination	Partial versus full vaccination
Survey period					
1998–1999	54.3 (53.7–54.9)	27.4 (26.9–27.9)	18.3 (17.9–18.8)	Ref	
2002–2004	47.9 (47.1–48.7)	32.1 (31.5–32.8)	20.0 (19.4–20.6)	1.57 (1.47–1.67)	1.51 (1.44–1.58)
2007–2008	56.0 (55.5–56.6)	34.6 (34.2–35.1)	9.4 (9.0–9.7)	0.92 (0.86–0.98)	1.58 (1.52–1.65)
Location					
Rural	49.4 (48.6–50.2)	32.3 (32.0–32.7)	18.3 (17.7–18.9)	Ref	
Urban	65.2 (63.8–66.6)	25.1 (24.0–26.2)	9.7 (9.2–10.3)	1.37 (1.26–1.49)	1.03 (0.98–1.07)
Religion					
Hindu	54.3 (52.9–55.7)	30.7 (30.1–31.2)	15.0 (14.1–15.9)	Ref	
Muslim	43.9 (42.4–45.4)	31.7 (30.9–32.5)	24.4 (23.2–25.6)	2.03 (1.89–2.18)	1.44 (1.37–1.51)
Christian	58.8 (56.5–61.1)	29.0 (27.6–30.5)	12.2 (10.8–13.5)	0.90 (0.76–1.07)	1.01 (0.92–1.12)
Other***	70.5 (69.0–72.0)	21.6 (20.2–22.9)	7.9 (7.1–8.8)	0.58 (0.50–0.69)	0.62 (0.56–0.67)
Social class					
General class	50.6 (49.5–51.7)	31.6 (30.9–32.3)	17.8 (16.8–18.7)	Ref	
Scheduled caste	47.1 (45.4–48.7)	35.7 (34.8–36.7)	17.2 (16.2–18.2)	1.29 (1.20–1.39)	1.11 (1.06–1.16)
Scheduled tribe	51.1 (49.8–52.4)	30.9 (30.3–31.6)	18.0 (17.0–18.9)	1.09 (0.99–1.19)	1.04 (0.98–1.11)
Other backward classes	61.7 (60.5–62.9)	26.5 (25.8–27.2)	11.8 (11.1–12.5)	1.42 (1.34–1.52)	1.16 (1.12–1.21)
Mother's age at birth of eligible child					
≤18	48.2 (46.7–49.8)	34.5 (33.5–35.4)	17.3 (16.1–18.5)	1.21 (1.12–1.32)	1.23 (1.17–1.30)
19–25	56.8 (55.7–57.9)	30.2 (29.7–30.7)	13.0 (12.3–13.7)	Ref	
26–35	51.2 (49.6–52.9)	29.6 (28.8–30.4)	19.2 (18.1–20.2)	1.05 (0.99–1.10)	0.95 (0.92–0.98)
>35	37.8 (35.8–39.8)	31.0 (29.7–32.4)	31.1 (29.4–32.9)	1.19 (1.08–1.32)	0.95 (0.88–1.03)
Mother's education					
High school and above (9 years & above)	76.9 (76.2–77.5)	20.3 (19.7–20.8)	2.8 (2.6–3.1)	Ref	
Middle (6–8 years of schooling)	65.1 (64.3–66.0)	28.2 (27.4–28.9)	6.7 (6.3–7.1)	1.17 (1.03–1.33)	1.19 (1.13–1.26)
Primary (1–5 years of schooling)	56.2 (55.4–56.9)	32.6 (31.8–33.3)	11.2 (10.7–11.8)	1.50 (1.32–1.70)	1.33 (1.27–1.41)
No schooling	37.4 (36.5–38.1)	35.8 (35.5–36.2)	26.8 (26.1–27.6)	2.61 (2.33–2.93)	1.77 (1.68–1.86)
Number of antenatal care visits					
≥7	78.5 (77.5–79.5)	18.6 (17.7–19.5)	2.9 (2.6–3.2)	Ref	
3–6	68.7 (68.1–69.3)	26.3 (25.8–26.8)	5.0 (4.7–5.3)	0.68 (0.58–0.80)	1.13 (1.06–1.20)
1–2	50.4 (49.6–51.1)	37.1 (36.5–37.7)	12.5 (12.1–13.0)	1.09 (0.92–1.28)	1.60 (1.50–1.70)
None	29.1 (28.3–30.1)	35.1 (34.6–35.6)	35.8 (34.9–36.7)	1.75 (1.50–2.06)	1.92 (1.78–2.07)
Maternal tetanus vaccination					
Yes	61.7 (60.7–62.7)	29.1 (28.5–29.7)	9.2 (8.7–9.7)	Ref	
No	26.2 (25.2–27.1)	35.1 (34.5–35.6)	38.7 (37.6–39.9)	2.82 (2.64–3.01)	1.35 (1.29–1.42)
Gender of eligible child					
Male	54.4 (53.1–55.7)	30.4 (29.8–31.1)	15.2 (14.4–16.0)	Ref	
Female	52.4 (51.1–53.4)	30.5 (29.9–31.0)	17.1 (16.2–18.0)	1.16 (1.10–1.21)	1.03 (1.00–1.06)
Place of delivery					
Institutional government	69.9 (69.2–70.6)	25.3 (24.6–25.9)	4.8 (4.6–5.1)	Ref	
Institutional private	71.7 (70.7–72.7)	23.1 (22.4–23.9)	5.2 (4.7–5.6)	1.11 (0.98–1.26)	1.07 (1.02–1.13)
Non-institutional	41.0 (40.2–41.8)	34.9 (34.6–35.3)	24.1 (23.4–24.8)	1.53 (1.41–1.67)	1.22 (1.17–1.27)
Vaccination card					
Yes (seen)	75.7 (75.0–76.4)	23.4 (22.7–24.1)	0.9 (0.7–1.0)	Ref	
Yes (not seen)	57.5 (56.8–58.2)	37.8 (37.1–38.3)	4.7 (4.5–5.1)	6.53 (5.51–7.75)	1.90 (1.83–1.97)
No	22.4 (21.6–23.1)	32.0 (31.4–32.5)	45.6 (44.8–46.4)	118.0 (100.24–138.83)	3.57 (3.43–3.72)

* Coverage proportions presented for combined DLHS surveys and are calculated using the total weighted sample of children in each covariate category as the denominator.
** Adjusted for type of dwelling, age of child in months and geographical region.
*** Other religions include Sikh, Buddhism, Jainism, Judaism and Atheism.

Please cite this article in press as: Francis MR et al. Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998–2008. Vaccine (2017), http://dx.doi.org/10.1016/j.vaccine.2017.08.026



Footnote:
1) N = 10 679, 11 751, 5 471 responses for DLHS - 1, DLHS - 2, DLHS - 3 respectively
2) DLHS-1 and DLHS-2 allowed only single responses, DLHS-3 allowed multiple responses
3) Demand and supply categorization of reported reasons based on standard operational practice
4) Reported reasons under the "others" category were unspecified and kept as such

Fig. 1. Reported reasons for non-vaccination among children aged 12–23 months of India: 1998–2008. (1) DLHS-1 and DLHS-2 allowed only single responses, DLHS-3 allowed multiple responses. (2) Demand and supply categorization of reported reasons based on standard operational practice [4]. (3) Reported reasons under the "others" category were unspecified and kept as such).

vaccinated. The findings of the secondary analysis restricting the analytical sample to the partially vaccinated children were generally consistent with those of the primary analysis (see supplemental Table 2).

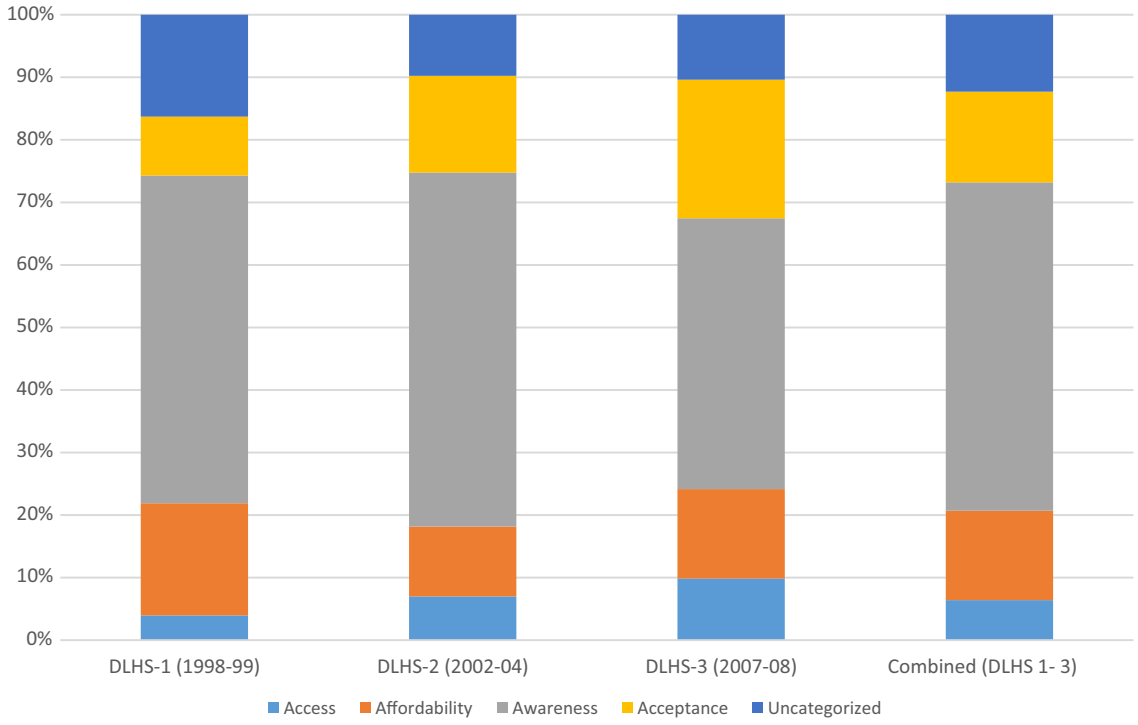
Across the three surveys, the most frequently occurring reason for non-vaccination was that mothers were "unaware of the need for immunization" (Fig. 1). Other noteworthy reasons were not knowing the place for and timing of vaccinations, fear of side-effects following vaccination, access to immunization facilities ("place of immunization too far") and the absence of health workers ("ANM absent"). Most reported reasons for non-vaccination could be categorized as issues of awareness, acceptance or affordability. The categorization of reported reasons for non-vaccination using the 5As taxonomy is available in Table 4. Four of the 17 reported reasons, mainly involving supply-side issues such as absence of health workers, vaccine stock outs and missed opportunities for vaccination could not be classified using the 5As taxonomy domains. Over the ten years spanning the surveys, issues of poor parental awareness (regarding the need for, place and timing of immunizations), acceptance of vaccines (including fear of side effects, lack of trust and false contraindications) and affordability (financial and non-financial costs) were the most important underlying reasons for non-vaccination among children aged 12–23 months in India (Fig. 2).

Table 4
Categorizing the reported reasons for non-vaccination among Indian children using the 5As taxonomy for Determinants of Vaccine Uptake [adapted from reference 14].

5A's taxonomy domains	Reported reason for non-vaccination
Access	Place of immunization too far
Affordability	Time of immunization inconvenient, Mother too busy, Financial problem, Family problem or mother ill
Awareness	Unaware of need for immunization, place of immunization unknown, time of immunization unknown
Acceptance	Child too young for immunization, Fear of side effects, No faith in immunization, child ill so not taken, child is a girl or customary
Activation	–
Uncategorized	ANM absent, vaccine not available, child ill, taken but not given, long waiting time

4. Discussion

India has the largest number of unvaccinated children globally. Our research indicates that the proportion of unvaccinated children decreased between 1998 and 2008; however the proportion of partially vaccinated children increased slightly for the same period, concurring with previous reports from India [27,28]. The increase in partially vaccinated children, while suboptimal, possibly implies that greater numbers of children are receiving at least some of the recommended UIP vaccines compared with earlier years. Persisting socio-demographic disparities in children's vaccination status were found to be associated with individual characteristics such as the child's gender, mother's education, maternal antenatal participation, receipt of maternal tetanus vaccination, place of delivery, religious preference and caste. Most reported reasons for non-vaccination could be categorized as issues of



Footnote:
1) N = 9 669, 11 081, 4 963, 25713 responses for DLHS - 1, DLHS - 2, DLHS - 3 & Combined surveys (DLHS 1 - 3) respectively
2) The 5As of the taxonomy are access, affordability, awareness, acceptance and activation [14].
3) None of the reported reasons could be categorized under activation.
4) Uncategorized reasons were mainly "supply-side" issues such as absence of health workers, missed opportunities for vaccination and vaccine stock outs.

Fig. 2. Reported reasons for non-vaccination among children 12–23 months of India categorized by the 5As taxonomy for Determinants of Vaccine uptake: 1998–2008. (1) The 5As of the taxonomy are access, affordability, awareness, acceptance and activation [14]. (2) None of the reported reasons could be categorized under activation. (3) Uncategorized reasons were mainly "supply-side" issues such as absence of health workers, missed opportunities for vaccination and vaccine stock outs.

awareness, acceptance and affordability related to routine childhood vaccinations.

Of the many potential demand-side factors, social determinants are known to have a significant impact on routine immunization programs in countries regardless of their income level [29]. They are also considered indicators of inequalities in access to immunization services or uptake of vaccinations among different populations [29,30]. In this study, children were more likely to be partially vaccinated in urban areas compared with rural areas, similar to the findings of a recent study using data from DLHS-3 [22]. An important reason for this might be the presence of underserved populations living in urban slums with limited access to primary health infrastructure and consequently routine immunization services compared with non-slum urban and rural dwellers [21,22]. Additionally, female children were more likely to be unvaccinated than males, potentially highlighting the chronic issue of gender discrimination for preventive health care within some Indian households [11,20].

Lower maternal education and antenatal participation, non-institutional delivery and non-receipt of maternal tetanus vaccination were found to be associated with higher odds of children being partially vaccinated and unvaccinated. The pathways through which maternal characteristics may influence immunization decisions for children are complex [31]. For example, previous research from India highlights the role of health knowledge and the ability to communicate in mediating the effect of maternal education on childhood immunization decisions [31]. Interventions to improve utilization of maternal health services, may help improve childhood immunization outcomes [22]. It is unclear if the associations between religion and caste with children's vaccination status represent differential access to routine immunization services or perceived barriers, health beliefs and lack of awareness regarding vaccinations in general [22,30]. Further research disentangling the role of supply-side and demand-side barriers to immunization and investigating the causal pathways through which important maternal and social characteristics influence decision-making for childhood vaccinations is needed to inform governmental interventions to improve uptake of routine vaccination in India.

Since socio-demographic characteristics are often difficult to interpret and modify, we also organized the mother's reported reasons for not vaccinating their children by adapting the "5As Taxonomy for Determinants of Vaccine Uptake", intended for non-socio-demographic determinants [14]. In addition to gaps in awareness, the categorization helped identify issues of acceptance and affordability as other important underlying reasons for non-vaccination among Indian children. These findings suggest that communication strategies to increase immunization coverage focusing on improving parental knowledge alone may not be sufficient to change vaccination behavior as previously indicated [32]. Although models elucidating parental decision-making for childhood vaccinations are available, studies examining the applicability of the existing theoretical frameworks in India are not available and the complex interplay of several social, cultural, political, economic and religious influences on parental decision-making for childhood vaccinations in India make the use of existing frameworks difficult. Therefore, contextual

Please cite this article in press as: Francis MR et al. Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998–2008. Vaccine (2017), http://dx.doi.org/10.1016/j.vaccine.2017.08.026

research investigating these factors in India is needed to develop interventions to improve vaccination acceptance rates [33–35]. Past and recent reports of vaccine refusal related to the OPV and DPT vaccines from different parts of the country and clustering of vaccine-refusing households can provide some insights on other dynamics affecting vaccine decisions. [36–38]. Expanding and leveraging the successful Social Mobilization Network (SMNet) approach used in the National Polio Eradication Programme, incorporating the use of local religious leaders and community influencers may improve trust between parents and health providers [39]. The Indian UIP may also consider parental time constraints through the organization of regular catch-up sessions for missed vaccinations and the wider use of mobile immunization reminder services such as the "vRemind" and "IAP-ImmunizeIndia" to help reduce India's immunization gap [40,41].

Large-scale, periodic surveys providing data on health indicators in India such as the DLHS and National Family Health Survey (NFHS) have typically focused on capturing a wide range of maternal and child health outcomes, including details on recommended vaccinations for the most recently born children [19]. As the DLHS survey is currently combined with the National Family Health Survey, it is important for future NFHS "women's questionnaires" to include questions on why children missed some or all vaccinations [17]. As demonstrated in this study, it is possible to categorize mother's reported reasons using an analytical framework such as the 5As Taxonomy to aid identification of the possible root causes for suboptimal vaccination among Indian children. To better capture issues of parental "acceptance" of childhood vaccination, the Parent Attitudes about Childhood Vaccination (PACV) short scale could be adapted for use in the NFHS surveys [42]. Also, since supply-side issues were consistently reported as important reasons for non-vaccination by mothers across the surveys, it may be valuable to include an additional dimension (a sixth "A") such as the "availability" of vaccinators, vaccines and timely vaccination services to the 5As Taxonomy, especially for use in developing countries such as India. Comparison of the 5As taxonomy categorization to standard categories (supply or demand-side) and the "Classification of Factors Affecting Receipt of Vaccines" are presented in Supplemental Table 3 [43].

Among the limitations of this study, the first is the use of relatively old datasets for analysis. The analysis was restricted to the first three DLHS rounds since the fourth round (DLHS-4) was not nationally representative. Furthermore, the NFHS datasets could not be utilized for analysis as its fourth round is currently underway and it does not include mother's reasons for not vaccinating their children. Even still, the use of the first three rounds of the DLHS datasets allowed pooling for the study sample, increasing analytical power and facilitating investigation of the various socio-demographic factors associated with suboptimal vaccination which are unlikely to change substantially over time. Second, the vaccination status of children was categorized using maternal recall in addition to vaccination card information. Because of differential recall, estimates of vaccine coverage and vaccination status may have been under or overestimated (Supplemental Table 4). Many earlier studies from India have conducted similar analyses combining immunization information based on maternal recall and vaccination cards and in our study, a vast majority of the unvaccinated children (89%) would have been excluded if the analyses were restricted to information from vaccination cards alone [7,12,22,23,26,28,44,45]. Third, a recent study observed age misreporting and likely underreporting of recent pregnancies among female respondents, highlighting potential selection and information biases in large scale surveys such as the DLHS [46]. Fourth, the DLHS surveys were cross-sectional in design, limiting the ability to draw causal inference from the observed associations. Fifth, the association of important characteristics such as parental employment, birth order and household size with vaccination status could not be assessed as those data was incomplete. Sixth, the wealth index for households in the first DLHS survey (DLHS-1) was not available, therefore type of dwelling was used as an "absolute" measure of household wealth to help quantify the level of poverty of survey households as opposed to wealth indices which are "relative" measures of wealth generally created using Demographic and Health Survey data [47].

5. Conclusions

This study utilized mixed methods to examine the socio-demographic and non-socio-demographic factors influencing suboptimal routine vaccination among Indian children. Persisting socio-demographic disparities in children's vaccination status were found to be associated with important childhood, maternal and household characteristics. This analysis found that gaps in awareness, acceptance and affordability (financial and non-financial costs) were the most important underlying reasons for non-vaccination among Indian children, but further research investigating the causal pathways through which important maternal and social characteristics influence decision-making for childhood vaccinations is needed to improve uptake of routine vaccination in India. Efforts to increase vaccine uptake should address parental fears related to vaccination to improve trust in government health services as part of ongoing social mobilization and programmatic communication strategies.

Authors' contribution

Study concept and design: MRF, JPN; Acquisition of data: MRF; Analysis and interpretation of data: MRF, JPN; Drafting of the manuscript: MRF, JPN; Critical revision of the manuscript for important intellectual content: All authors; Statistical analysis: MRF; Obtained funding: JPN; Study supervision: JPN; Final approval: All authors.

Funding

MRF was supported by the International Doctoral Programme in Epidemiology (IPPE), Health Sciences, Faculty of Social Sciences, University of Tampere, Finland.

Conflict of interest

The LSHTM (to which HL belongs) have received funding from Novartis for maternal immunization acceptance research; funding from GSK for advising on vaccine hesitancy issues; and funding from both GSK and Merck to convene research symposiums. HJL served on the Merck Vaccines Strategic Advisory Board. None of the funders had any role in the preparation of this paper and none of the other authors declare any competing interests.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.vaccine.2017.08.026.

References

[1] Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, Bassani DG, et al. Global, regional, and national causes of child mortality in 2008: a systematic analysis. The Lancet 2010;375:1969–87. http://dx.doi.org/10.1016/S0140-6736(10)60549-1.

[2] Vashishtha VM, Kumar P. 50 years of immunization in India: progress and future. Indian Pediatr 2013;50:111–8.
[3] Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, et al. Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. The Lancet 2012;379:2151–61. http://dx.doi.org/10.1016/S0140-6736(12)60560-1.
[4] India Coverage Evaluation Survey 2009-2010 | GHDx n.d. http://ghdx.healthdata.org/record/india-coverage-evaluation-survey-2009-2010 [accessed November 8, 2016].
[5] Mission Indradhanush to Put Vaccination Efforts on High Speed n.d. http://pib.nic.in/newsite/mbErel.aspx?relid=117759 [accessed January 5, 2017].
[6] Laxminarayan R, Ganguly NK. India's vaccine deficit: why more than half of Indian children are not fully immunized, and what can—and should—be done. Health Aff (Millwood) 2011;30:1096–103. http://dx.doi.org/10.1377/hlthaff.2011.0405.
[7] Singh PK. Trends in child immunization across geographical regions in India: focus on urban-rural and gender differentials. PLoS One 2013;8. http://dx.doi.org/10.1371/journal.pone.0073102. e73102.
[8] Barman D, Dutta A. Access and barriers to immunization in West Bengal, India: quality matters. J Health Popul Nutr 2013;31:510–22.
[9] Johri M, Chandra D, Koné GK, Dudeja S, Sylvestre M-P, Sharma JK, et al. Interventions to increase immunisation coverage among children 12–23 months of age in India through participatory learning and community engagement: pilot study for a cluster randomised trial. BMJ Open 2015;5. http://dx.doi.org/10.1136/bmjopen-2015-007972. e007972.
[10] Jheeta M, Newell J. Childhood vaccination in Africa and Asia: the effects of parents' knowledge and attitudes. Bull World Health Organ 2008;86:419.
[11] Corsi DJ, Diego BG, Kumar R, Awasthi S, Jotkar R, Kaur N, et al. Gender inequity and age-appropriate immunization coverage in India from 1992 to 2006. BMC Int Health Hum Rights 2009;9:S3. http://dx.doi.org/10.1186/1472-698X-9-S1-S3.
[12] Ghosh A, Laxminarayan R. Demand- and supply-side determinants of diphtheria-pertussis-tetanus nonvaccination and dropout in rural India. Vaccine 2017;35:1087–93. http://dx.doi.org/10.1016/j.vaccine.2016.12.024.
[13] Favin M, Steinglass R, Fields R, Banerjee K, Sawhney M. Why children are not vaccinated: a review of the grey literature. Int Health 2012;4:229–38. http://dx.doi.org/10.1016/j.inhe.2012.07.004.
[14] Thomson A, Robinson K, Vallée-Tourangeau G. The 5As: A practical taxonomy for the determinants of vaccine uptake. Vaccine 2016;34:1018–24. http://dx.doi.org/10.1016/j.vaccine.2015.11.065.
[15] International Institute for Population Sciences (IIPS). Reproductive and Child Health Project, Rapid Household Survey (Phase I and II) 1998–1999: India 2001.
[16] International Institute for Population Sciences (IIPS). District Level Household and Facility Survey (DLHS – 2), 2002–2004: India 2006.
[17] International Institute for Population Sciences (IIPS). District Level Household and Facility Survey (DLHS – 3), 2007–2008: India 2010.
[18] International Institute for Population Sciences (IIPS). District Level Household and Facility Survey (DLHS – 4), 2012–2013: India 2014.
[19] Dandona R, Pandey A, Dandona L. A review of national health surveys in India. Bull World Health Organ 2016;94:286–296A. http://dx.doi.org/10.2471/BLT.15.158493.
[20] Mathew JL. Inequity in childhood immunization in India: a systematic review. Indian Pediatr 2012;49:203–23. http://dx.doi.org/10.1007/s13312-012-0063-z.
[21] Devasenapathy N, Jerath SG, Sharma S, Allen E, Shankar AH, Zodpey S. Determinants of childhood immunisation coverage in urban poor settlements of Delhi, India: a cross-sectional study. BMJ Open 2016;6. http://dx.doi.org/10.1136/bmjopen-2016-013015. e013015.
[22] Shrivastwa N, Gillespie BW, Kolenic GE, Lepkowski JM, Boulton ML. Predictors of vaccination in India for children aged 12–36 months. Am J Prev Med 2015;49:S435–44. http://dx.doi.org/10.1016/j.amepre.2015.05.008.
[23] Sissoko D, Trottier H, Malvy D, Johri M. The influence of compositional and contextual factors on non-receipt of basic vaccines among children of 12–23-month old in India: a multilevel analysis. PLOS One 2014;9. http://dx.doi.org/10.1371/journal.pone.0106528. e106528.
[24] Pande RP, Yazbeck AS. What's in a country average? Wealth, gender, and regional inequalities in immunization in India. Soc Sci Med 1982;2003(57):2075–88.
[25] Keja K, Chan C, Hayden G, Henderson RH. Expanded programme on immunization. World Health Stat Q Rapp Trimest Stat Sanit Mond 1988;41:59–63.
[26] Kumar C, Singh PK, Singh L, Rai RK. Socioeconomic disparities in coverage of full immunisation among children of adolescent mothers in India, 1990–2006: a repeated cross-sectional analysis. BMJ Open 2016;6. http://dx.doi.org/10.1136/bmjopen-2015-009768. e009768.
[27] Kumar A, Mohanty SK. Socio-economic differentials in childhood immunization in India, 1992–2006. J Popul Res 2011;28:301. http://dx.doi.org/10.1007/s12546-011-9069-y.
[28] Prusty RK, Kumar A. Socioeconomic dynamics of gender disparity in childhood immunization in India, 1992–2006. PLoS ONE 2014;9:e104598. http://dx.doi.org/10.1371/journal.pone.0104598.
[29] Glatman-Freedman A, Nichols K. The effect of social determinants on immunization programs. Hum Vaccines Immunother 2012;8:293–301. http://dx.doi.org/10.4161/hv.19003.
[30] Rainey JJ, Watkins M, Ryman TK, Sandhu P, Bo A, Banerjee K. Reasons related to non-vaccination and under-vaccination of children in low and middle income countries: findings from a systematic review of the published literature, 1999–2009. Vaccine 2011;29:8215–21. http://dx.doi.org/10.1016/j.vaccine.2011.08.096.
[31] Vikram K, Vanneman R, Desai S. Linkages between maternal education and childhood immunization in India. Soc Sci Med 1982;2012(75):331–9. http://dx.doi.org/10.1016/j.socscimed.2012.02.043.
[32] Nyhan B, Reifler J, Richey S, Freed GL. Effective messages in vaccine promotion: a randomized trial. Pediatrics 2014:peds.2013-2365. doi: 10.1542/peds.2013-2365.
[33] Janz NK, Becker MH. The health belief model: a decade later. Health Educ Q 1984;11:1–47. http://dx.doi.org/10.1177/109019818401100101.
[34] Godin G, Kok G. The theory of planned behavior: a review of its applications to health-related behaviors. Am J Health Promot AJHP 1996;11:87–98.
[35] Public trust in vaccination: an analytical framework | Indian Journal of Medical Ethics n.d. <http://ijme.in/articles/public-trust-in-vaccination-an-analytical-framework/?galley=html> [accessed May 26, 2017].
[36] Onnela J-P, Landon BE, Kahn A-L, Ahmed D, Verma H, O'Malley AJ, et al. Polio vaccine hesitancy in the networks and neighborhoods of Malegaon, India. Soc Sci Med 1982;2016(153):99–106. http://dx.doi.org/10.1016/j.socscimed.2016.01.024.
[37] Orr D. India's last bastion of polio at "tipping point". Bull World Health Organ 2007;85:828–9. http://dx.doi.org/10.2471/BLT.07.031107.
[38] Polio risk over dose refusal. The Telegraph n.d. <http://www.telegraphindia.com/1160405/jsp/bihar/story_78360.jsp> [accessed December 7, 2016].
[39] Siddique AR, Singh P, Trivedi G. Role of social mobilization (Network) in polio eradication in India. Indian Pediatr 2016;53(Suppl 1):S50–6.
[40] vRemind – Immunisation Awareness and Vaccination Reminders n.d. <http://vremind.org/> [accessed January 13, 2017].
[41] Immunize India n.d. <http://immunizeindia.org/> [accessed January 16, 2017].
[42] Oladejo O, Allen K, Amin A, Frew PM, Bednarczyk RA, Omer SB. Comparative analysis of the Parent Attitudes about Childhood Vaccines (PACV) short scale and the five categories of vaccine acceptance identified by Gust et al.. Vaccine 2016. http://dx.doi.org/10.1016/j.vaccine.2016.08.046.
[43] Hadler S, Dietz V, Okwo-Bele J, Cutts FT. Immunization in developing countries. Vaccines. 5th ed.; 2008. p. 1541–72.
[44] Valadez JJ, Weld LH. Maternal recall error of child vaccination status in a developing nation. Am J Public Health 1992;82:120–2. http://dx.doi.org/10.2105/AJPH.82.1.120.
[45] George K, Victor S, Abel R. Reliability of mother as an informant with regard to immunisation. Indian J Pediatr 1990;57:588–90.
[46] Borkotoky K, Unisa S. Indicators to examine quality of large scale survey data: an example through district level household and facility survey. PLoS ONE 2014;9. doi: 10.1371/journal.pone.0090113.
[47] Morris SS, Carletto C, Hoddinott J, Christiaensen LJM. Validity of rapid estimates of household wealth and income for health surveys in rural Africa. J Epidemiol Commun Health 2000;54:381–7. http://dx.doi.org/10.1136/jech.54.5.381.

Please cite this article in press as: Francis MR et al. Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998–2008. Vaccine (2017), http://dx.doi.org/10.1016/j.vaccine.2017.08.026