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Francis, MR; Nohynek, H; Larson, H; Balraj, V; Mohan, VR; Kang, G; Nuorti, JP (2017) Factors associated with routine childhood vaccine uptake and reasons for non-vaccination in India: 1998-2008. *Vaccine*. ISSN 0264-410X DOI: <https://doi.org/10.1016/j.vaccine.2017.08.026>

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DOI: [10.1016/j.vaccine.2017.08.026](https://doi.org/10.1016/j.vaccine.2017.08.026)

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

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33 **Abstract**

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

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

44 **Results:** The pooled dataset contained information on 178,473 children 12–23 months of
45 age; 53%, 32% and 15% were fully vaccinated, partially vaccinated and unvaccinated
46 respectively. Compared with the 1998-1999 survey, children in the 2007–2008 survey
47 were less likely to be unvaccinated (Adjusted Prevalence Odds Ratio (aPOR): 0.92,
48 95%CI = 0.86 – 0.98) but more likely to be partially vaccinated (POR: 1.58, 95%CI = 1.52
49 – 1.65). Vaccination status was inversely associated with female gender, Muslim religion,
50 lower caste, urban residence and maternal characteristics such as low educational
51 attainment, home delivery, lack of antenatal participation and non-receipt of maternal
52 tetanus vaccination. The mother’s reported reasons for non-vaccination indicated gaps in
53 awareness, acceptance and affordability (financial and non-financial costs) related to
54 routine vaccinations.

55 **Conclusions:** Persisting socio-demographic disparities related to partial- and non-
56 vaccination were associated with many childhood, maternal and household characteristics.

57 Further research investigating the causal pathways through which important maternal and
58 social characteristics influence decision-making for childhood vaccinations is much needed
59 to improve uptake of routine vaccination in India. Also, governmental efforts to increase
60 uptake would benefit from addressing parental fears related to vaccination and improving
61 trust in government health services as part of ongoing social mobilization and
62 communication strategies.

63 **Keywords:** socioeconomic factors, partial or non-vaccination, routine immunization, EPI

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

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79 **Introduction**

80 Globally about one-third of the annual vaccine preventable child deaths or 500,000 deaths
81 occur in India [1,2]. While most vaccine preventable deaths in India are due to pneumonia
82 and diarrhea, complete immunization with existing routine vaccines against tuberculosis,
83 diphtheria, pertussis and tetanus, polio, measles, hepatitis B and *H. influenzae* type b are
84 essential to avert the associated mortality, morbidity and to prevent future outbreaks of
85 these vaccine preventable diseases [3]. However, despite almost three decades of the
86 UIP, the proportion of children aged 12-23 months receiving the full schedule of
87 vaccinations in India is around 61% and for third dose DPT (DPT3) coverage is 72%, still
88 below the global average of 86% [4]. The persisting low routine immunization coverage
89 implies that one in three children born every year still do not receive complete protection
90 against the diseases currently covered by the UIP, placing them at the highest risk of
91 mortality and morbidity [2,5].

92 India's slow progress to achieving universal immunization for all children has generally
93 been attributed to its sheer population size, high growth rate, geographic and cultural
94 diversity and limited healthcare spending [6,7]. However, large inter-state and inter-district
95 disparities in immunization coverage have helped uncover important supply and demand-
96 side factors associated with uptake of routine vaccinations [7–9]. Supply-side factors
97 generally include a lack of trained personnel to manage and deliver immunization services,
98 poor relationship between health care workers and mothers, inconvenient timing or
99 location of immunization services and even vaccine stock outs [6,8,10]. Demand-side
100 factors associated with routine vaccination uptake however are complex and often multi-
101 faceted. Previous research from India tends to highlight socio-demographic characteristics
102 associated with uptake such as child's gender, order of birth, place of delivery, maternal
103 age at childbirth, parental education, caste and religious preference, household wealth and

104 location (urban or rural) , [6–8,11,12]. Of late, non-socio-demographic demand-side issues
105 such as awareness regarding the need for and timing of routine childhood vaccinations,
106 fears regarding some or all routine vaccines and parental beliefs regarding false
107 contraindications to routine vaccinations have been reported as reasons linked to partial-
108 vaccination and non-vaccination of Indian children [4,12,13]. As, the Indian Government
109 aims to boost full immunization coverage of UIP vaccines to 90% through the Mission
110 Indradhanush initiative by 2020, it is important to track the various socio-demographic and
111 non-socio-demographic factors influencing suboptimal vaccination over the years to
112 identify key areas of intervention and further research.

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

120 **Methods**

121 **Data Source, Sampling and Survey questionnaire**

122 The DLHS cross-sectional surveys are conducted periodically to monitor and assess
123 reproductive and child health program indicators in every district of India. To date, four
124 rounds of the DLHS have been completed (DLHS-1 in 1998–99, DLHS-2 in 2002–04,
125 DLHS-3 in 2007–08 & DLHS-4 in 2012-13). To date, four rounds of the DLHS have been
126 completed (DLHS-1 in 1998–99, DLHS-2 in 2002–04, DLHS-3 in 2007–08 & DLHS-4 in
127 2012-13). Data from DLHS-4 were excluded because the survey was not nationally

128 representative (DLHS-4 covered 336 of 640 Indian districts). Each DLHS round employed
129 a similar systematic, multi-stage stratified sampling scheme. Additional detail on the
130 survey design and calculation of sampling weights are available in the Appendix and
131 elsewhere [15–18]. Interviews with currently married (or ever married) women and with
132 any adult family member (aged 18 years and above) collected information for the
133 “women’s questionnaire” and “household questionnaire” respectively. We used information
134 from the “women’s questionnaire” containing relevant information on socio-demographic
135 characteristics and childhood immunization information. The type and number of questions
136 providing information on household, maternal and child characteristics and immunization
137 histories were generally similar for the DLHS surveys, however, there were more
138 questions about child and maternal health from DLHS-1 to DLHS-4 [19] (See Appendix for
139 more details on questionnaire). In the DLHS, immunization histories for the last two
140 surviving children were obtained from the vaccination card of the children. If the
141 vaccination card was not available immunization data were based on maternal recall. The
142 study sample comprised the most recently born children aged 12-23 months at the time of
143 survey to limit the influence of poor maternal recall on immunization histories of older
144 children. Also, for consistency and pooling we further restricted analysis to children of
145 mothers who were currently married (*i.e.* ever-married mothers were excluded as they
146 were only interviewed in DLHS-3) and aged 15 – 44 years at the time of survey (*i.e.*
147 mothers aged >44 years from DLHS-3 were excluded).

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150 **Socio-demographic variables**

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

163

164 **Outcome variable**

165 The current Indian UIP schedule recommends one dose of BCG vaccine at birth (or as
166 soon as possible), three doses of DPT, OPV and Hepatitis B (added in 2007) or
167 pentavalent vaccine (available in some Indian states since 2011) and OPV vaccination
168 provided at 6, 10 and 14 weeks of age and one dose of measles vaccine at 9 months of
169 age. The main outcome of study was the vaccination status of children 12 – 23 months of
170 age, defined using EPI recommendations which were in use during the surveys as follows
171 [22,25]:

- 172 1) Fully vaccinated – children who received one dose of BCG, three doses of DPT,
173 three doses of OPV (excluding the zero dose) and one dose of measles vaccine by
174 12 months of age

- 175 2) Partially vaccinated – children who received at least one but not all the
176 recommended vaccines by 12 months of age
- 177 3) Unvaccinated – children who did not receive any of the recommended vaccines by
178 12 months of age

179

180 **Statistical Analysis**

181 Data from the three DLHS surveys were pooled to examine the socio-demographic factors
182 associated with children's vaccination status over the ten-year period covered by the
183 surveys. Similar pooling of data to assess trends and determine predictors of immunization
184 coverage have been reported using the National Family Health Survey (India's
185 Demographic & Health Survey)) datasets [26]. Because of the complex, stratified sampling
186 design, appropriate weighting of coverage proportions and regression estimates was done
187 using the supplied national sampling weights for each survey. Univariate regression
188 analysis was performed to examine associations between the socio-demographic
189 variables and children's vaccination status for all surveys combined (see Appendix for
190 technical details). All the socio-demographic variables which had a significant univariate
191 association with vaccination status at the $p \leq 0.05$ level were included in the multivariate
192 regression analysis to examine factors associated with partial-vaccination and non-
193 vaccination compared with full vaccination for children aged 12 – 23 months [22]. Also,
194 since the outcome of children's vaccination status had three levels, a pooled multinomial
195 logistic regression adjusted for age of the child, type of dwelling, survey period and
196 geographic region. Results of the multivariate regression modelling are presented as
197 adjusted Prevalence Odds Ratio's (aPOR's) with 95% Confidence Interval's (CIs). The
198 relative importance of each socio-demographic variable in the multivariate regression
199 model was assessed using Wald Test p -values. We also performed secondary analyses

200 restricting the analytical sample to the partially vaccinated children to explore differences
201 in the factors associated with vaccination status based on whether children received “very
202 few” vaccines (1 – 2 doses), “some” vaccines (3 – 5 doses) or “almost all” vaccines (6 – 7
203 doses). The survey analyses were performed using the “svy” package in STATA version
204 12 and figures made using Excel 2013.

205 **Categorization of reasons for non-vaccination**

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

216

217 **Results**

218 There were a total of 58,777 (31% of all surveyed children), 58,416 (30%), 61,280 (28%)
219 and 178,473 (30%) eligible children aged 12 – 23 months in the DLHS-1, DLHS-2, DLHS-3
220 and the combined surveys respectively. Of these children, 74% lived in rural locations and
221 38% in mud households. Fifty-three percent of the children were male and 78% of the
222 children were Hindu (Supplemental Table 1). Also, 50% of the children had mothers
223 without any formal schooling and 59% of mothers had non-institutional deliveries.

224 Coverage of important UIP vaccine doses and children's vaccination status for the
225 individual and combined surveys are presented in Table 2. Of the eligible children, 32%
226 did not have a vaccination card and 30% reportedly had vaccination cards which could not
227 be presented at the time of survey. Overall, coverage of BCG vaccination was highest
228 (81%) and coverage of the third dose DPT (DPT3) vaccine was 62%, similar to third dose
229 OPV (68%) and first dose measles (66%) vaccines. Coverage of BCG and measles
230 vaccination increased from 74 % to 87% and 60% to 74% respectively from 1998-1999
231 (DLHS-1) to 2007-2008 (DLHS-3). However, DPT3 coverage decreased from 66% to 61%
232 for the same period. Fifty-three percent of the eligible children were fully vaccinated, with
233 32.1% and 14.6% partially vaccinated and unvaccinated respectively. The proportion of
234 unvaccinated children was reduced from 18% to 9% and the proportion of partially
235 vaccinated children increased from 27% to 35% from the 1998-1999 (DLHS-1) period to
236 the 2007-2008 (DLHS-3) period.

237 Results of the pooled multivariate analysis are presented in Table 3. Children in the 2007-
238 2008 (DLHS-3) period were less likely to be unvaccinated (aPOR: 0.92, 95%CI = 0.86 –
239 0.98) and more likely to be partially vaccinated compared to the 1998 -1999 period (DLHS-
240 1) (aPOR: 1.58, 95% CI = 1.52 – 1.65). After adjusting for age of the child, type of
241 dwelling, survey period and geographic region, female children were more likely to be
242 unvaccinated than males (aPOR: 1.16, 95%CI = 1.10 – 1.21)and children born at home
243 were more likely to be unvaccinated and partially vaccinated compared to children born in
244 governmental institutions. Children living in urban households (compared with rural
245 households) were more likely to be unvaccinated (aPOR: 1.37, 95% CI = 1.26 –
246 1.49).Compared to Hindu children, Muslim children were more likely to be unvaccinated
247 (aPOR: 2.03, 95% CI = 1.89 – 2.18) and partially vaccinated (aPOR: 1.44, 95%CI = 1.37 –
248 1.51).And, relative to children belonging to the general class, those belonging to scheduled

249 caste and other backward classes were more likely to be unvaccinated. Decreasing
250 maternal education, antenatal care participation, non-receipt of maternal tetanus
251 vaccination and non-retention of children’s vaccination cards were similarly associated
252 with increased odds of children being unvaccinated and partially vaccinated. The findings
253 of the secondary analysis restricting the analytical sample to the partially vaccinated
254 children were generally consistent with those of the primary analysis (see supplemental
255 Table 2).

256 Across the three surveys, the most frequently occurring reason for non-vaccination was
257 that mothers were “unaware of the need for immunization” (Figure 1). Other noteworthy
258 reasons were not knowing the place for and timing of vaccinations, fear of side-effects
259 following vaccination, access to immunization facilities (“place of immunization too far”)
260 and the absence of health workers (“ANM absent”). Most reported reasons for non-
261 vaccination could be categorized as issues of awareness, acceptance or affordability. Four
262 of the 17 reported reasons, mainly involving supply-side issues such as absence of health
263 workers, vaccine stock outs and missed opportunities for vaccination could not be
264 classified using the 5As taxonomy domains. Over the ten years spanning the surveys,
265 issues of poor parental awareness (regarding the need for, place and timing of
266 immunizations), acceptance of vaccines (including fear of side effects, lack of trust and
267 false contraindications) and affordability (financial and non-financial costs) were the most
268 important underlying reasons for non-vaccination among children aged 12-23 months in
269 India (Figure 2).

270

271 **Discussion**

272 India has the largest number of unvaccinated children globally. Our research indicates that
273 the proportion of unvaccinated children decreased between 1998 and 2008, the proportion
274 of partially vaccinated children increased slightly for the same period, concurring with
275 previous reports from India [27,28]. The increase in partially vaccinated children, while
276 suboptimal, possibly implies that greater numbers of children are receiving at least some
277 of the recommended UIP vaccines compared with earlier years. Persisting socio-
278 demographic disparities in children's vaccination status were found associated with
279 individual characteristics such as child gender, mother's education, maternal antenatal
280 participation, receipt of maternal tetanus vaccination, place of delivery, religious
281 preference and caste. And, most reported reasons for non-vaccination could be
282 categorized as issues of awareness, acceptance and affordability related to routine
283 childhood vaccinations.

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

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

311 Since socio-demographic characteristics are often difficult to interpret and modify, we also
312 attempted to organize mother's reported reasons for not vaccinating their children using
313 the "5As Taxonomy for Determinants of Vaccine Uptake", intended for non-socio-
314 demographic determinants [14]. In addition to gaps in awareness, the categorization
315 helped identify issues of acceptance and affordability as other important underlying
316 reasons for non-vaccination among Indian children. These findings suggest that
317 governmental communication strategies to increase immunization coverage focusing on
318 improving parental knowledge alone may not be sufficient to change vaccination behavior
319 as previously indicated [32]. Although models elucidating parental decision-making for
320 childhood vaccinations are available, studies examining the applicability of the existing

321 theoretical frameworks in India are not available and the complex interplay of several
322 social, cultural, political, economic and religious influences on parental decision-making for
323 childhood vaccinations in India make the use of existing frameworks difficult. Therefore,
324 contextual research investigating these factors in India is needed to develop interventions
325 to improve vaccination acceptance rates [33–35]. Past and recent reports of vaccine
326 refusal related to the OPV and DPT vaccines from different parts of the country and
327 clustering of vaccine-refusing households can provide some insights on other dynamics
328 affecting vaccine decisions. [36–38]. Expanding and leveraging the successful Social
329 Mobilization Network (SMNet) approach used in the National Polio Eradication
330 Programme, incorporating the use of local religious leaders and community influencers
331 may improve trust between parents and health providers [39]. The Indian UIP may also
332 consider parental time constraints through the organization of regular catch-up sessions
333 for missed vaccinations and the wider use of mobile immunization reminder services such
334 as the “vRemind” and “IAP-ImmunizeIndia” to help reduce India’s immunization gap [40,41].

335 Large-scale, periodic surveys providing data on health indicators in India such as the
336 DLHS and National Family Health Survey (NFHS) have typically focused on capturing a
337 wide range of maternal and child health outcomes, including details on recommended
338 vaccinations for the most recently born children [19]. As the DLHS survey is currently
339 combined with the National Family Health Survey, it is important for future NFHS “women’s
340 questionnaires” to include questions on why children missed some or all vaccinations [17].
341 As demonstrated in this study, it is possible to categorize mother’s reported reasons using
342 an analytical framework such as the 5As Taxonomy to aid identification of the possible root
343 causes for suboptimal vaccination among Indian children. To better capture issues of
344 parental “acceptance” of childhood vaccination, the Parent Attitudes about Childhood
345 Vaccination (PACV) short scale could be adapted for use in the NFHS surveys [42]. Also,

346 since supply-side issues were consistently reported as important reasons for non-
347 vaccination by mothers across the surveys, it may be valuable to include an additional
348 dimension (a sixth “A”) such as the “availability” of vaccinators, vaccines and timely
349 vaccination services to the 5As Taxonomy, especially for use in developing countries such
350 as India. Comparison of the 5As taxonomy categorization to standard categories (supply
351 or demand-side) and the “Classification of Factors Affecting Receipt of Vaccines” are
352 presented in Supplemental Table 3 [43].

353 Among the important limitations of this study, the first is the use of relatively old datasets
354 for analysis. The analysis was restricted to the first three DLHS rounds since the fourth
355 round (DLHS-4) was not nationally-representative. Furthermore, the NFHS datasets could
356 not be utilized for analysis as its fourth round is currently underway and it does not include
357 mother’s reasons for not vaccinating their children. Even still, the use of the first three
358 rounds of the DLHS datasets allowed pooling for the study sample, increasing analytical
359 power and facilitating investigation of the various socio-demographic factors associated
360 with suboptimal vaccination which are unlikely to change drastically over time. Second, the
361 vaccination status of children was categorized using maternal recall in addition to
362 vaccination card information. Because of differential recall, estimates of vaccine coverage
363 and vaccination status may have been under or overestimated (Supplemental Table 4).

364 Many earlier studies from India have conducted similar analyses combining immunization
365 information based on maternal recall and vaccination cards and in our study, a vast
366 majority of the unvaccinated children (89%) would have been excluded if the analyses
367 were restricted to information based on maternal recall alone [7,12,22,23,26,28,44,45]. Third,
368 a recent study observed age misreporting and likely underreporting of recent pregnancies
369 among female respondents, highlighting potential selection and information biases in large
370 scale surveys such as the DLHS [46]. Fourth, the DLHS surveys were cross-sectional in

371 design, limiting the ability to draw causal inference from the observed associations. Fifth,
372 the association of important characteristics such as parental employment, birth order and
373 household size with vaccination status could not be assessed as those data was
374 incomplete. Sixth, the wealth index for households in the first DLHS survey (DLHS-1) was
375 not available, therefore type of dwelling was used as an “absolute” measure of household
376 wealth to help quantify the level of poverty of survey households as opposed to wealth
377 indices which are “relative” measures of wealth generally created using Demographic and
378 Health Survey data [47].

379

380 **Conclusions**

381 This study utilized mixed methods to examine the socio-demographic and non-socio-
382 demographic factors influencing suboptimal routine vaccination among Indian children.
383 Persisting socio-demographic disparities in children’s vaccination status were found to be
384 associated with important childhood, maternal and household characteristics. This analysis
385 found that gaps in awareness, acceptance and affordability (financial and non-financial
386 costs) were the most important underlying reasons for non-vaccination among Indian
387 children, but further research investigating the causal pathways through which important
388 maternal and social characteristics influence decision-making for childhood vaccinations is
389 much needed to improve uptake of routine vaccination in India. Governmental efforts to
390 increase uptake would benefit from addressing parental fears related to vaccination and
391 improving trust in government health services as part of ongoing social mobilization and
392 programmatic communication strategies.

393

394 **Authors’ contributions**

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

399 **Funding**

400 MRF was supported by the Department of Epidemiology, SOC Health Sciences, University
401 of Tampere, Finland.

402 **Conflict of interest**

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

409

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542 **Tables**543 **Table 1:** Definitions and contributing factors of the “5As Taxonomy for Determinants of
544 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

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548 **Table 2:** Vaccination proportions for Indian children aged 12 - 23 months, DLHS1-3

Category	Weighted percentages (95% CI)					Relative change (%)*	P-value **
	DLHS-1 (1998-99)	DLHS-2 (2002-04)	DLHS-3 (2007-08)	Combined surveys (DLHS 1 - 3)			
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	
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	<0.001
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	
<i>Very few (1 - 2)</i>	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
<i>Some (3 - 5)</i>	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	
<i>Almost all (6 - 7)</i>	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	

549 N = 58 777, 58 416 & 61 279 for DLHS-1, DLHS-2 & DLHS-3 respectively

550 BCG: Bacillus Calmette - Guerin, DPT: Diphtheria-Pertussis-Tetanus, OPV: Oral Polio Vaccine

551 *Relative change calculated as ((DLHS1%/DLHS3%)-1)

552 **P-value of trend from Chi-square using Rao-Scott design adjustment

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555 **Table 3:** Results of multivariate regression modeling for pooled DLHS datasets

Covariates	Weighted proportions (95%CI)*			Adjusted Prevalance 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)	

556 * Coverage proportions presented for combined DLHS surveys and are calculated using the total weighted
 557 sample of children in each covariate category as the denominator

558 ** Adjusted for type of dwelling, age of child in months and geographical region

559 *** Other religions include Sikh, Buddhism, Jainism, Judaism and Atheism

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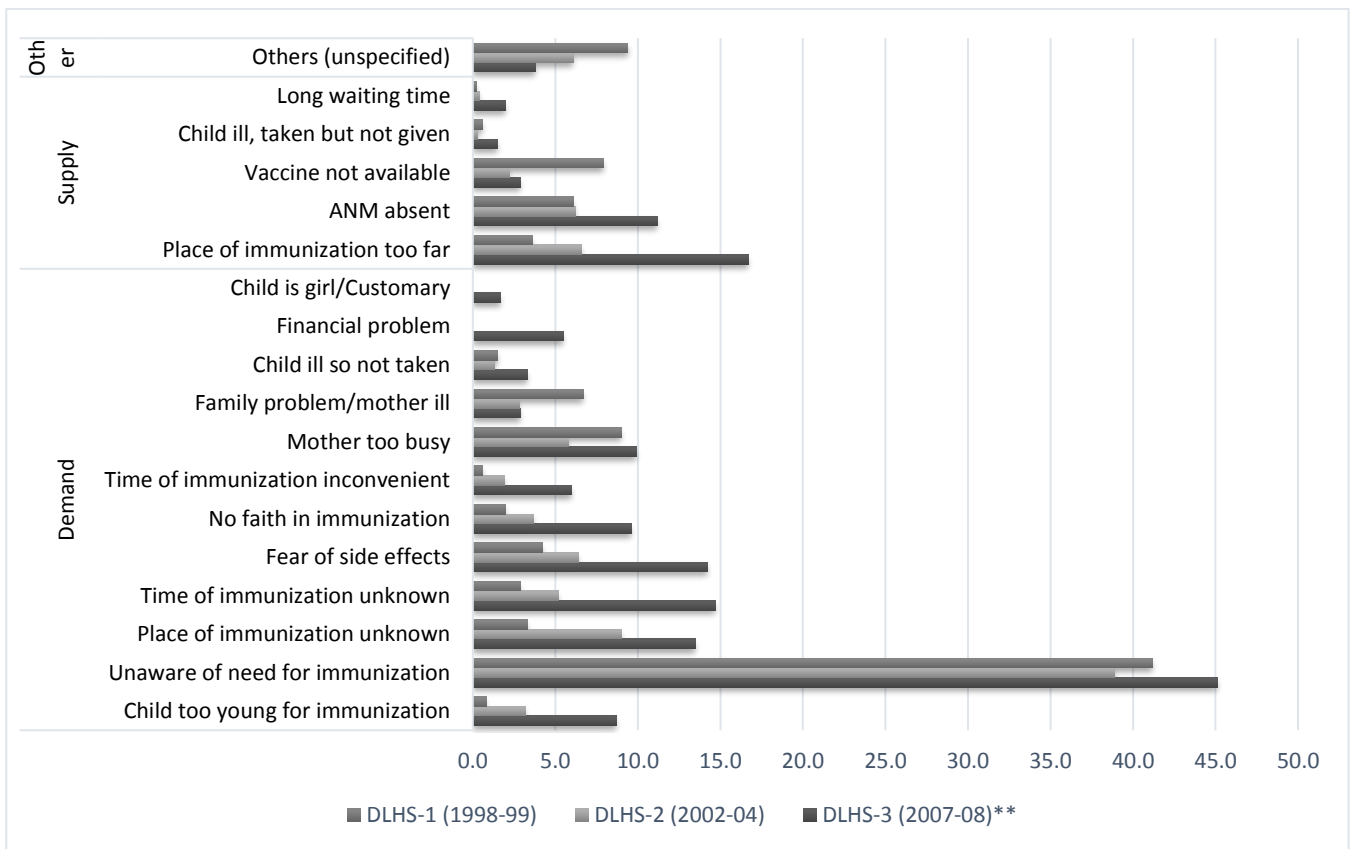
562 **Table 4:** Categorizing the reported reasons for non-vaccination among Indian children
 563 using the 5As taxonomy for Determinants of Vaccine Uptake [14]

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

564

565 **Figures**

566 **Figure 1:** Reported reasons for non-vaccination among children aged 12-23 months of
 567 India: 1998 – 2008



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569 ** Footnote:

- 570 1) DLHS-1 and DLHS-2 allowed only single responses, DLHS-3 allowed multiple responses
- 571 2) Demand and supply categorization of reported reasons based on standard operational practice [4]
- 572 3) Reported reasons under the "others" category were unspecified and kept as such

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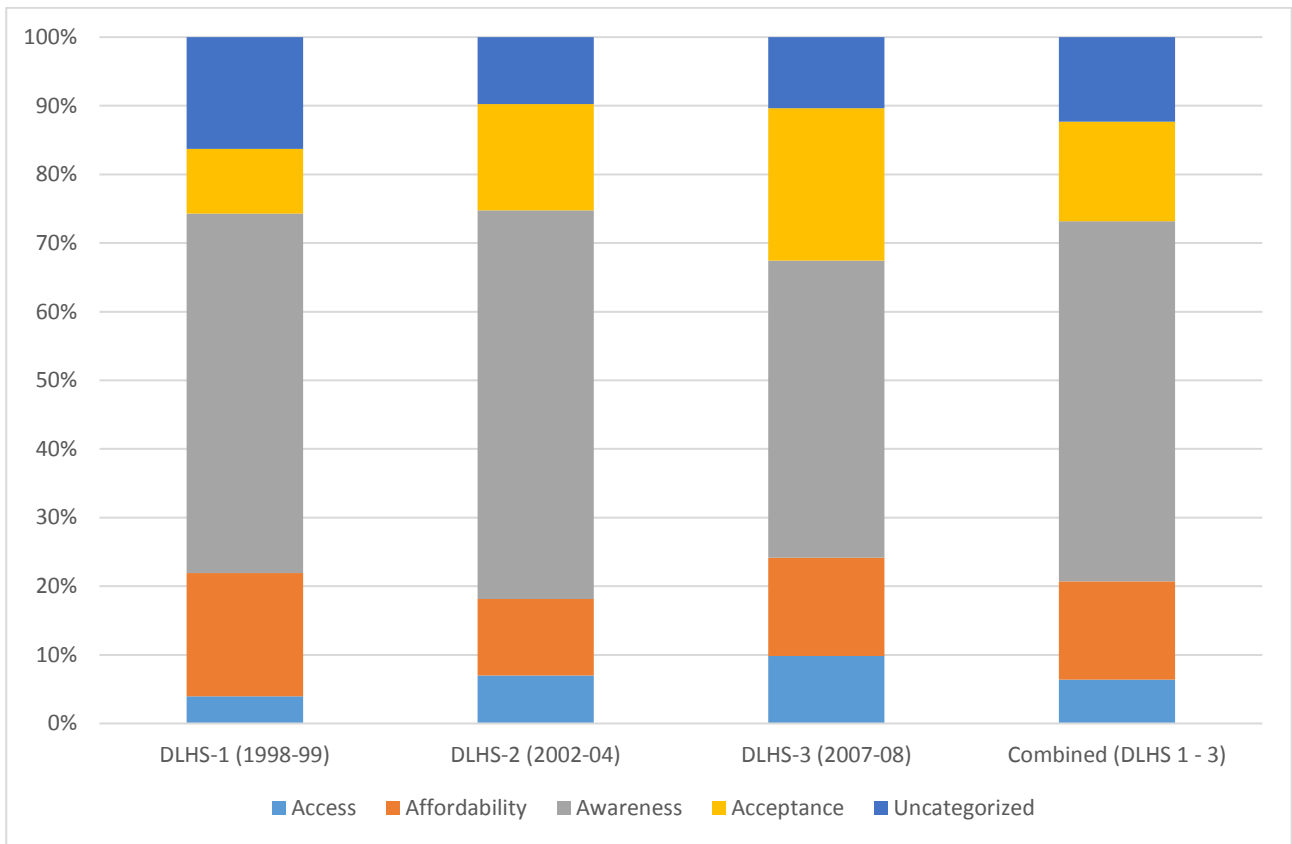
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583 **Figure 2:** Reported reasons for non-vaccination among children 12-23 months of India
 584 categorized by the 5As taxonomy for Determinants of Vaccine uptake: 1998 - 2008



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586 *Footnote:

- 587 1) The 5As of the taxonomy are access, affordability, awareness, acceptance and activation [14].
 588 2) None of the reported reasons could be categorized under activation.
 589 3) Uncategorized reasons were mainly “supply-side” issues such as absence of health workers,
 590 missed opportunities for vaccination and vaccine stock outs.