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# Immunisation coverage in rural–urban migrant children in low and middle-income countries (LMICs): a systematic review and meta-analysis

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## ABSTRACT

**Background** The majority of children who die from vaccine-preventable diseases (VPDs) live in low-income and middle-income countries (LMICs). With the rapid urbanisation and rural–urban migration ongoing in LMICs, available research suggests that migration status might be a determinant of immunisation coverage in LMICs, with rural–urban migrant (RUM) children being less likely to be immunised.

**Objectives** To examine and synthesise the data on immunisation coverage in RUM children in LMICs and to compare coverage in these children with non-migrant children.

**Methods** A multiple database search of published and unpublished literature on immunisation coverage for the routine Expanded Programme on Immunisation (EPI) vaccines in RUM children aged 5 years and below was conducted. Following a staged exclusion process, studies that met the inclusion criteria were assessed for quality and data extracted for meta-analysis.

**Results** Eleven studies from three countries (China, India and Nigeria) were included in the review. There was substantial statistical heterogeneity between the studies, thus no summary estimate was reported for the meta-analysis. Data synthesis from the studies showed that the proportion of fully immunised RUM children was lower than the WHO bench-mark of 90% at the national level. RUMs were also less likely to be fully immunised than the urban-non-migrants and general population. For the individual EPI vaccines, all but two studies showed lower immunisation coverage in RUMs compared with the general population using national coverage estimates.

**Conclusions** This review indicates that there is an association between rural–urban migration and immunisation coverage in LMICs with RUMs being less likely to be fully immunised than the urban non-migrants and the general population. Specific efforts to improve immunisation coverage in this subpopulation of urban residents will not only reduce morbidity and mortality from VPDs in migrants but will also reduce health inequity and the risk of infectious disease outbreaks in wider society.

## INTRODUCTION

Migrants are an expanding population of growing global health importance. There are approximately 750 million internal migrants (those who move within their country) and about 214 million international migrants (those who cross national borders) worldwide.<sup>1</sup> Population expansion in urban areas of low and middle-income countries (LMICs) has largely been driven by internal rural–urban

migration.<sup>2–3</sup> Between 1995 and 2005, the urban population in LMICs grew by an average of 1.2 million people weekly.<sup>4</sup> China in 2010, documented over 221 million rural–urban migrants; a 117% increase from the year 2000.<sup>5</sup> Such speed of urban growth poses a challenge to the capacity of the health system in LMICs to meet the health needs of the growing urban population<sup>3–6</sup> and rural–urban migration might be a determinant of immunisation coverage in LMICs<sup>7–11</sup> with evidence of disparities in coverage within urban areas<sup>2–3–12</sup> and between recent and long-term migrants. Increased population mobility coupled with low routine vaccine coverage of migrants has been an important factor in recent measles and polio outbreaks in LMICs.<sup>13–14</sup> This has been attributed to the characteristics of urban areas (high density, living in close proximity) which provide an environment favourable for outbreaks and rapid spread of diseases.

The theories of migrant disruption and migrant adaptation have been used to explain the relationship between rural–urban migration and immunisation coverage.<sup>15–16</sup> Migrant disruption proposes that migration disrupts the already established social support networks of migrant families bringing about social isolation and interfering with child immunisation uptake. Migrant adaptation proposes that the observed migrant-native differential can be ascribed to the failure of migrants to adjust to sociocultural norms or utilise health services in the receiving urban area and livelihood insecurity.<sup>15–17–19</sup> This underscores the unintended negative effects of rural–urban migration.

Following the launching of the Expanded Programme on Immunisation (EPI) in 1974, global immunisation coverage rose from 5% to 84% DTP3 coverage in 2013.<sup>20</sup> Immunisation is the most cost-effective and successful public health investment for reducing morbidity and mortality in children, averting 2 to 3 million deaths yearly world-wide<sup>21–22</sup> and preventing illness, disability from vaccine preventable diseases (VPDs). Despite this, 22.6 million children are still not reached by routine immunisation services.<sup>23</sup> WHO uses DTP3 or OPV3 and Measles vaccine coverage as indicators for health system performance and tracking progress towards Millennium Development Goal (MDG) 4—to reduce the 1990 mortality rate among children under-5 years old by two-thirds,<sup>24–25</sup> respectively.

While immunisation is the most cost-effective way to reduce morbidity and mortality in children, there is evidence to suggest that migrant children



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**Table 1** Search strategy in MEDLINE

Search ID	Search terms and filters	Number of hits
#1	Child terms Filters: Infant (Birth to 23 months) Preschool (2–5 years)	1 270 466
#2	Migration terms Filter: Human	36 639
#3	Immunisation terms Filter: Human	257 701
#4	#1 AND #2 AND #3	478

are less likely to be immunised. However, to date there has been no systematic examination of the data on immunisation coverage in migrant children. The main objectives of this review therefore are to examine immunisation coverage in rural-to-urban migrant (RUM) children and to compare coverage in these children with non-migrant children.

## METHODS

### Search for studies

We registered the protocol on PROSPERO and followed PRISMA guidelines. A systematic search for relevant studies was designed and conducted by the authors in consultation with an information specialist. The following databases were searched from inception to 17 May 2014: MEDLINE, EMBASE (1974 to 17 May 2014), Cumulative Index to Nursing and Allied Health Literature, global health library, global health and ProQuest.

The search employed a combination of free text, thesaurus terms and MeSH terms in different variations, with explosion of narrow terms to increase the yield of the search (see online supplementary appendix S1 for a full list of search terms). The reference lists of identified studies and papers citing selected articles were also carefully examined for relevant studies. A search for grey literature was also undertaken through the ProQuest database and organisational websites such as WHO. Five authors were contacted for possible clarification of certain items in their studies. No language or time limit was applied and studies were translated if necessary (table 1).

### Inclusion and exclusion criteria

The inclusion and exclusion criteria are shown in table 2. Included studies were limited to those conducted in LMICs as defined by the World Bank<sup>26</sup> and those reporting coverage for routine EPI vaccines.

### Extraction and classification of data

Data was extracted by the two authors independently. Author names, study date, title, participants, size, outcome, confounders controlled for and findings were extracted. Data was collected on immunisation coverage for individual vaccines. We used WHO definition of full vaccination: a child is considered fully vaccinated when the 'standard six' vaccines—BCG, diphtheria-tetanus-pertussis (DTP) (3 doses), polio (3 doses) and measles vaccines are received before reaching 1 year of age. In countries at risk for yellow-fever, hepatitis B, *Haemophilus influenzae* type b (Hib); these may be added.<sup>27</sup> Additional information was requested from authors if data was not reported in a suitable format for data synthesis.

### Quality assessment of included studies

The Newcastle-Ottawa Scale (NOS) adapted for cross-sectional studies was used for this review as all the studies that met the inclusion criteria had cross-sectional design. A study can score a maximum of 10.

To determine the quality of studies, the selection of study participants, clear definition of migrant status, power calculation, response rates, control for bias and confounding, outcome assessment, study participants' representativeness of the rural-urban migrant community and appropriateness of statistical tests were considered.

Studies were not excluded from the review on the basis of quality.

### Statistical analysis

The proportion of fully immunised RUM and urban non-migrant (UNM) children and the CIs were calculated using the Wilson's<sup>28</sup> procedure without continuity correction. The effect size (in this case the proportion of fully immunised RUM) and CIs derived for all studies were entered into Stata IC 13(64 bit) for a random-effects meta-analysis.

**Table 2** Inclusion and exclusion criteria

	Inclusion	Exclusion
Participants	<ul style="list-style-type: none"> <li>▶ History of Rural-to-Urban migration within low-and-middle-income country (LMIC)</li> <li>▶ Children under the age of 5 years</li> </ul>	<ul style="list-style-type: none"> <li>▶ Non-migrants (rural and urban), rural-rural migrants</li> <li>▶ Studies in which migrants' origin is not rural (eg, urban-rural, urban-urban migrants)</li> <li>▶ Studies with no mention of migration status or the migration status is unclear</li> </ul>
Outcome	<ul style="list-style-type: none"> <li>▶ Quantitative coverage of any/all of the WHO recommended routine vaccines under the original Expanded Programme on Immunisation (EPI). These are: BCG, diphtheria-tetanus-pertussis, oral polio, measles and recently added hepatitis B and <i>Haemophilus influenzae</i> type B vaccines. As well vaccines relevant to country-specific EPI schedule.</li> <li>▶ Immunisation status assessed objectively using child's immunisation records or health facility data and maternal/care-giver recall</li> </ul>	<ul style="list-style-type: none"> <li>▶ Quantitative coverage of non-routine EPI vaccines</li> <li>▶ Supplementary immunisation activities (SIAs) and campaigns</li> <li>▶ Studies assessing Immunity to VPDs</li> </ul>
Other	<ul style="list-style-type: none"> <li>▶ Observational studies</li> <li>▶ Any publication date</li> <li>▶ Any language</li> <li>▶ Published and unpublished data</li> </ul>	<ul style="list-style-type: none"> <li>▶ Qualitative studies</li> <li>▶ Policy papers without original data</li> </ul>

VPDs, vaccine-preventable diseases.

Data for the general population was extracted from the demographic health surveys (DHS) for Nigeria,<sup>29</sup> India<sup>30</sup> and National Health Services Survey (NHSS) for China<sup>31 32</sup> matching in date as closely as possible. Coverage data for individual vaccines were compared with the WHO 90% coverage benchmark for each vaccine. Comparison of coverage between RUM and UNM/general population were made by meta-analysing the raw data using Stata and the results presented as risk ratios. As a result of the substantial heterogeneity ( $I^2 > 75\%$ ), no overall effect size is reported and studies are presented narratively. Subgroup analysis was attempted as a means of investigating and explaining heterogeneity.

## RESULTS

The search yielded a total of 1163 studies. Four additional studies were identified from other sources including one conference paper<sup>33</sup> obtained from a non-database search and three studies from scanning of reference lists. These were included in the review. After removal of 282 duplicates, 885 abstracts were screened and 835 records were excluded. Fifty full-text articles were assessed for possible inclusion and 39 articles were

excluded. A total of 11 studies were included in the review. The summary of the exclusion process is shown in figure 1.

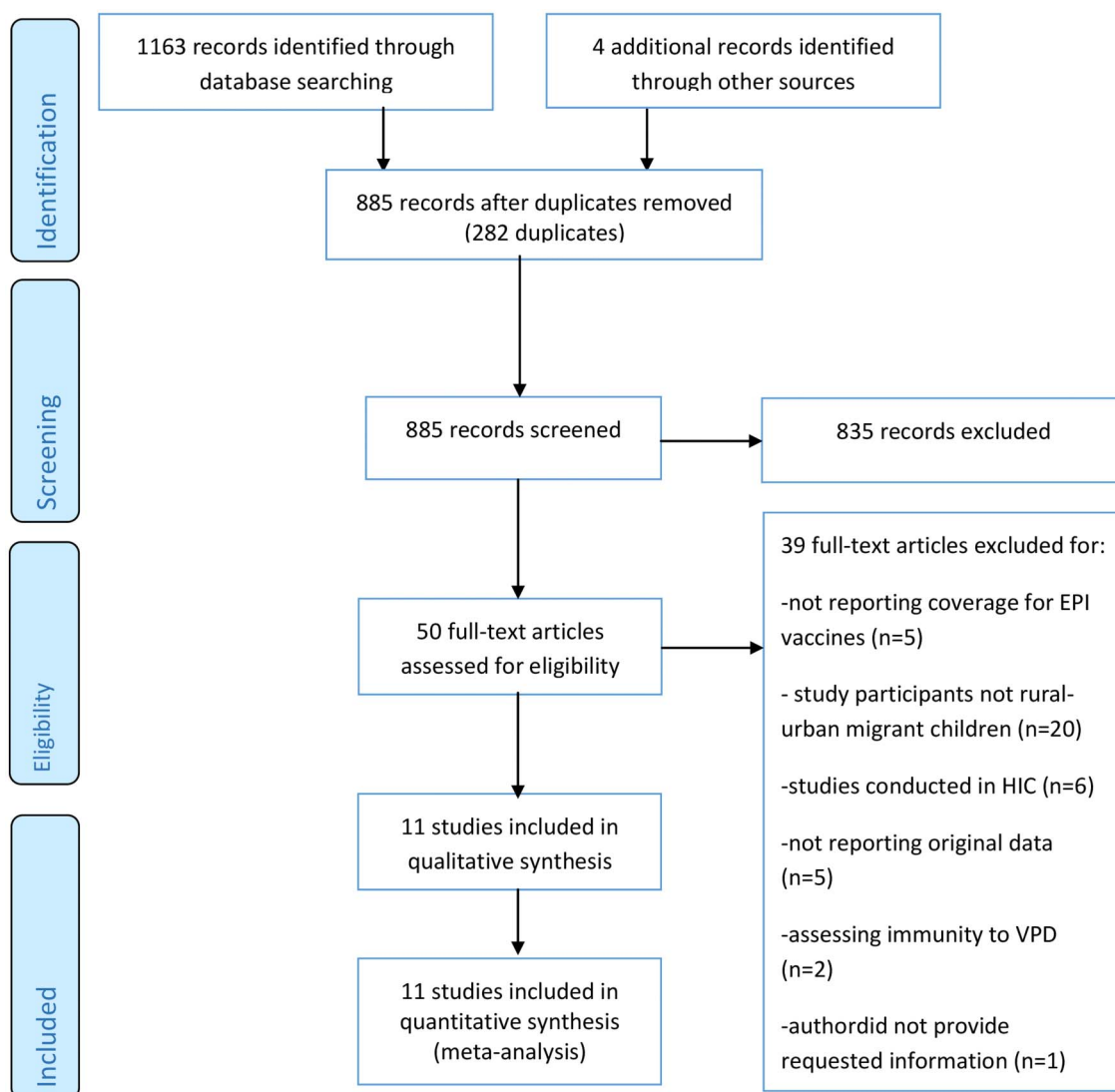
A summary of the characteristics and findings of included studies is presented in online supplementary file 1.

The quality assessment scores of selected studies ranged from 3 to 10. See table 3.

### Description of included studies

The 11 included studies<sup>2 15 18 33-40</sup> were conducted between 2000 and 2014. Of these, one was from Nigeria<sup>15</sup> and five each from China<sup>18 34 37 38 40</sup> and India.<sup>2 33 35 36 39</sup> All studies were cross-sectional design with varying sampling methods, three of which were based on WHO-advocated cluster sampling technique.<sup>41</sup> Supplementary data was obtained for one study after correspondence with the author.<sup>33</sup> The number of study participants ranged from 77 to 6029 with a total of 18 912 participants across all studies and 9730 (51%) of these were RUMs.

Ten studies had data on full immunisation coverage in RUM, four of these compared full immunisation coverage between RUM and the urban non-migrants. Six reported coverage levels for the following EPI vaccines: BCG, OPV, DTP, HBV, Measles



**Figure 1** Summary of exclusion process. EPI, Expanded Programme on Immunisation; VPD, vaccine-preventable diseases; HIC, high-income countries.

vaccines. One study assessed coverage for measles containing vaccine alone as its primary outcome.<sup>38</sup>

Kusuma *et al*<sup>35</sup> and Hu *et al*<sup>18</sup> further divided RUM into recent migrants and settled migrants this was used to assess whether length of stay in a new environment influences the association between rural–urban migration and immunisation coverage. All studies assessed the crude or up-to-date immunisation coverage (all doses were counted not just the valid doses)<sup>27 40</sup> and two studies assessed the valid and/or age-appropriate immunisation<sup>34 40</sup> in addition.

All studies were based on interviewer administered semistructured or structured questionnaires. Immunisation coverage was assessed in included studies by using either ‘Card plus history’<sup>2 15 18 33 35–37 39</sup> or ‘Card only’.<sup>34 38 40</sup>

Owing to considerable statistical heterogeneity between the studies,  $I^2$  value of 99.8% from the random-effects meta-analysis of studies for the proportion of fully vaccinated RUM children, summary estimates are not presented.

#### Proportion of fully vaccinated RUM children

Ten studies provided data on fully immunised RUM children<sup>2 15 18 33–37 39 40</sup> and showed a low proportion of RUMs are fully vaccinated according to the EPI schedule. The proportion of fully vaccinated RUM children in each study was lower than the WHO target of 90% coverage at the national level.

#### Full vaccination by migration status

Overall, four studies<sup>2 15 33 39</sup> reported comparison of full immunisation coverage between RUMs and urban non-migrants. RUMs were significantly less likely to be fully immunised compared with urban non-migrants in all studies (see figure 2). Antai also found that rural non-migrants were more likely to be immunised than RUMs (OR=1.43 in favour of rural non-migrants after adjusting for demographic and socioeconomic variables). In Tamoghna’s study, no RUM child was fully vaccinated.

Kusuma *et al*<sup>35</sup> and Hu *et al*<sup>18</sup> further assessed coverage by recent and settled migrant status. In both studies, settled migrants had higher odds of full immunisation than recent migrants with adjusted OR of 2.41 (95% CI 1.59 to 3.65)<sup>35</sup> and 2.19 (1.55 to 5.38)<sup>18</sup> respectively (figure 2).

Full vaccination in RUM children compared with the general population

In all studies, RUM children were significantly less likely to be fully immunised than the general population.

#### Coverage estimates for individual vaccines

Five studies reported data on BCG coverage, six studies reported OPV, DPT, HBV coverage and seven on MCV. Each vaccine is compared with its national coverage estimate for the corresponding year of study (see table 4). WHO benchmark for national coverage for individual vaccines is 90%.

In all studies except Kusuma *et al*<sup>35</sup> and Sun *et al*,<sup>40</sup> coverage estimates for individual vaccines was lower in RUM than the national coverage for the corresponding years.<sup>2 15 18 34</sup> In the studies by Kusuma *et al*<sup>35</sup> and Sun *et al*,<sup>40</sup> DTP3, OPV3, Measles coverage was higher in RUM than the NC.

Sun *et al*’s<sup>40</sup> study recorded an estimate in RUM children equal to the national average for that year for HBV3. In Kusuma *et al*,<sup>35</sup> HBV3 and BCG coverage in RUM was higher than the national estimates.

## DISCUSSION

The results suggest that rural-to-urban migrants in China, India and Nigeria are less likely to be fully immunised than urban non-migrants and the general population. Within RUM populations, recent migrants had even lower coverage than the settled migrants. The coverage rates for individual vaccines were found to be lower in RUM populations than the national immunisation coverage estimates for each vaccine in all but two studies;<sup>35 40</sup> furthermore all coverage estimates for RUM children are below the WHO benchmark of 90% coverage for each vaccine.

These findings are consistent with findings from other studies<sup>7–9 42–49</sup> including studies by Islam and Azad,<sup>46</sup> Chan *et al*<sup>7</sup> and Mathew,<sup>49</sup> in Bangladesh, Cambodia and India, respectively, which found associations between RUM status and low childhood immunisation coverage.

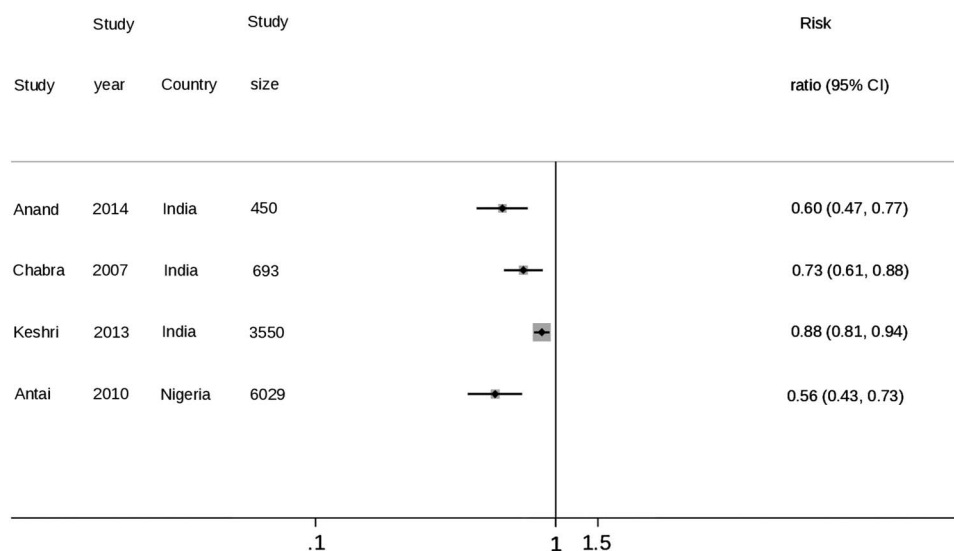
The lower immunisation rate in recent migrants compared to settled migrants concurs with Islam and Azad’s<sup>46</sup> study and gives credence to the theory of migrant adaptation as settled migrants have adapted to the culture, norms and living conditions and so utilisation of health services may be better than the

**Table 3** Quality assessment of included studies using the Newcastle-Ottawa Scale adapted for cross-sectional studies

First author, year	Selection				Comparability Comparable participants; control for potential confounders	Outcome		Total
	Clear definition of migration status	Sample size calculation reported	Participants representative of RUM group	Non-respondents documented		Objective only and/or subjective assessment	Appropriate statistical test	
Anand, 2014	X	X	X			X		4
Antai, 2010	X		X X	X	X	X	x	7
Chhabra, 2007		X	X X		X	X	x	6
Guo, 2000	X		X X			X		4
Han, 2014	X	X	X		X	X X	x	7
Hu, 2013	X	X	X X	X	X	X	x	8
Huang, 2011			X			X X		3
Keshri, 2013	X		X X	X	X	X	x	7
Kusuma, 2010	X	X	X X	X	X	X	x	8
Sun, 2005	X	X	X X	X X	X	X X	x	10
Tamoghna, 2011	X		X			X		3

Based on an adapted form of the Newcastle-Ottawa scale for cohort studies adapted by Herzog *et al* for cross-sectional studies <http://www.biomedcentral.com/1471-2458/13/154>. RUM, rural–urban migrants.

Risk ratio of full vaccination in RUM children compared with urban non-migrants



**Figure 2** Full vaccination by migration status, random effects model without summary estimate.

recent migrants who are more vulnerable and without social networks. Poorer adaptation also explains lower immunisation coverage in RUM children compared to urban non-migrants and it is significant that regardless of their duration of stay, RUMs do not attain living standards and levels of access to health services equal to that of the urban native population.<sup>35–46</sup>

The finding of higher immunisation coverage in rural non-migrants documented by Antai could be attributed to the contribution of outreach teams via supplementary immunisation activities and campaigns<sup>10–44–50</sup> and better community mobilisation and participation in rural areas.

The three countries (India, China and Nigeria) represented in this review have been listed by WHO as countries with very low immunisation coverage<sup>23–25</sup> and like other LMICs they have high rates of internal migration. DTP3 and measles coverage rates are indicators of immunisation service delivery and progress towards achieving the MDG4-reducing child mortality, respectively. DTP3, measles, BCG, OPV3 and HBV3 estimates in RUM children were lower than national estimates showing the disparities and inequity in vaccination within the countries that would otherwise remain concealed in national averages alone. This underscores the need for reporting of spatially and socially disaggregated data in order to reveal health inequities which may not be readily apparent.

These results have important public health implications for the eradication of VPDs such as polio and measles. Nigeria for instance, is still polio endemic and measles outbreaks in China have been related to RUM children having lower vaccination rates. According to the United Nation Research Institute for Social Development, RUM children have been at the forefront of China's measles epidemic.<sup>51</sup> Targeting RUM children for vaccination should be prioritised in eradication efforts in these countries.

The coverage estimates by Kusuma *et al*<sup>35</sup> and Sun *et al*,<sup>40</sup> though lower than the WHO target for the assessed vaccines (except BCG and OPV3), reported coverage estimates higher than other studies and also higher in RUM children than national averages. This might be explained by immunisation 'pocketing': these two studies may have been conducted in clusters of relatively higher coverage rates.

### Strengths and limitations

This study involved a thorough, systematic search of multiple databases to retrieve all relevant studies without language or time restrictions and it is the first time, to our knowledge, that data on immunisation coverage on the rural–urban migrant children in LMICs has been synthesised. However, the data was only available from three LMICs—China, India and Nigeria and

**Table 4** Summary table for individual vaccine coverage in RUM versus national coverage estimates

Study author, year, country	Immunisation coverage (in per cent)									
	DTP3		OPV3		MEASLES		HBV		BCG	
	RUM	NC	RUM	NC	RUM	NC	RUM	NC	RUM	NC
Antai 2010, Nigeria	12	54	27	54	21	56	–	–	30	62
Kusuma 2010, India	73	72	72	70	76	74	62	37	91	87
Anand 2014, India	33	72	35	70	30	74	32	67	78	87
Sun 2005, China	88	87	91	87	88	86	84	84	–	–
Hu 2013, China	53	99	53	99	46	99	55	99	33	99
Han 2014, China	74	99	75	99	72	99	72	99	76	99

DTP3, diphtheria-tetanus-pertussis; OPV3, oral polio vaccine; HBV, hepatitis B vaccine; RUM, rural–urban migrants; NC, national coverage from WHO-UNICEF estimates for corresponding year [http://apps.who.int/immunization\\_monitoring/globalsummary/timeseries/tswucoveredtp3.html](http://apps.who.int/immunization_monitoring/globalsummary/timeseries/tswucoveredtp3.html)



although all large populous countries, the data from the majority of LMICs is missing. This lack of data from other LMICs is an important global health issue; as most migration occurs within LMICs, these countries host the majority of these vulnerable populations. The consequences of infectious disease outbreaks for these countries, often with fragile health systems, are likely to be considerable. This lack of data therefore not only raises issues of generalisability of the review's findings but more importantly, highlights an important gap in global health research.

There was also substantial heterogeneity between studies and though all studies were cross-sectional, they had a range of different sampling methods which may partly account for the observed heterogeneity.

There is no universally accepted definition of an urban area hence the definitions used in the various studies varied from definitions based on administrative boundaries, population density and/or proportion of population engaged in non-agricultural occupations. Variations existed in the populations from which the samples were drawn. Hence, participants in some studies were not fully representative of the entire RUM population as they were drawn from RUMs in construction sites<sup>36</sup> only or schools.<sup>37</sup>

The use of caregiver recall in the assessment of immunisation coverage in addition to vaccination card can introduce recall bias from the respondents. The use of data from national surveys can also be problematic and means that the risk ratios presented must be interpreted with caution. These national surveys are not designed or conducted in a uniform manner across all countries. Furthermore for some surveys, the year of conduct did not correspond to the same year as the individual studies. The DHS used for Nigeria was conducted in 2008 which was the closest possible for Antai's 2010 study. In India, the most recent UNICEF national coverage survey (2009) was used and for China the only available data for full immunisation coverage was from a 2003 NHSS.

Health inequities are an important aspect of migrant health and these findings demonstrate that low vaccination rates are a particular health disadvantage for RUM children. The findings indicate the need for appropriate surveillance and targeted efforts to improve vaccination rates tailored to the specific needs of this heterogeneous population. Evidence has shown improvement in immunisation of highly mobile populations by mass immunisation campaigns and outreach<sup>52 53</sup> using community-based approaches<sup>44</sup> and these gains from mass campaigns can be sustained by strengthening health systems for routine immunisation.<sup>48</sup> Policymakers should be aware that the provision of immunisation services to RUMs, whether in formal or informal settlements, has a wider beneficial impact on the overall health status of the entire urban population—not only for the RUMs. Thus, the health of RUMs should be prioritised in urban health planning and policy processes.

## CONCLUSION

Migration is an issue of growing global health importance and the majority of migrants come from and remain in LMICs. These are the same countries where, despite the increase in the burden of non-communicable diseases, infectious diseases remain an important threat to health and where health systems are most challenged. This systematic review has shown that RUMs are less likely to be fully vaccinated than urban non-migrants and the general population in Nigeria, China and India. This highlights the urgent need to address inadequacies in the effective delivery of vaccinations to RUMs in order to

reduce the risks associated with the spread of communicable diseases in the whole population and to reduce the impact of the existing 'double-burden of disease which stretches the capacity of the health system of most LMICs. Failure to ensure adequate immunisation coverage in RUMs could have far-reaching adverse consequences. It will create clusters of undervaccinated children within populations which may affect herd immunity;<sup>34</sup> impede efforts towards control and eradication of polio, measles and other VPDs; increase the vulnerability of the rest of the population to major disease outbreaks and potentially reverse the gains of decreasing child mortality so far achieved in these countries.

## What is already known on this subject

- ▶ Migration may be a determinant of immunisation uptake. Some evidence suggests that rural–urban migration confers an advantage to migrants as better health services are available in urban areas.
- ▶ Very little is known about the role of rural–urban migration on childhood immunisation coverage as the focus has been on international migrants.

## What this study adds

This systematic review and meta-analysis of observational studies has shown that rural–urban migrant children are less likely to be fully immunised compared to their urban non-migrant counterparts and the general population. This has implications for vaccine-preventable disease control and eradication efforts and the risk of disease outbreaks in urban areas.

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**Contributors** ABA designed the protocol for this systematic review and meta-analysis and conducted the database searches. ABA screened the abstracts of all the studies identified from the search for eligibility. The full texts of the relevant articles were read by ABA and EP independently for possible inclusion. Data was extracted from the included studies independently by ABA and EP as a means of double-checking. ABA carried out the meta-analysis. The writing of the manuscript was carried out by ABA and EP.

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## REFERENCES

- 1 World Health Organisation (WHO). Humanitarian Health Action: migrant health. 2014. [http://www.who.int/hac/techguidance/health\\_of\\_migrants/en/](http://www.who.int/hac/techguidance/health_of_migrants/en/) (accessed 3 May 2014).
- 2 Anand S, Verma P, Sinha U, et al. Evaluation of primary immunization coverage in migratory versus non-migratory labour population of urban area in Bhopal city. *Pediatric Oncall* 2014;11. <http://www.pediatriconcall.com/Journal/Article/FullText.aspx?artid=841&type=J&tid=&imgid=&reportid=450&tbltype=> (accessed 3 May 2014).
- 3 Montgomery MR. The health of urban populations in developing countries. In: *United Nations Department of Economic and Social Affairs Population Division, Population Distribution, Urbanisation, Internal Migration and Development: an international perspective*. United Nations Publications, 2011:264–85. <http://www.un.org/esa/population/publications/PopDistribUrbanization/PopulationDistributionUrbanization.pdf>
- 4 World Health Organisation. Urbanization and health. *Bull World Health Organ* 2010;88:245–6. <http://www.who.int/bulletin/volumes/88/4/10-010410/en/> (accessed 5 May 2014).
- 5 Xiang-jiang Z. Analysis of population movement and distribution based on sixth census. *Popul Econ* 2011;6:24–7.
- 6 Alirio E, Getaz L, Stoll B, et al. Urbanisation and infectious diseases in a globalised world. *Lancet Infect Dis* 2011;11:131–41.
- 7 Chan Soeung S, Grundy J, Duncan R, et al. From reaching every district to reaching every community: analysis and response to the challenge of equity in immunization in Cambodia. *Health Policy Plan* 2013;28:526–35.
- 8 Cutts FT, Diallo S, Zell ER, et al. Determinants of vaccination in an urban population in Conakry, Guinea. *Int J Epidemiol* 1991;20:1099–106.
- 9 Barreto TV, Rodrigues LC. Factors influencing childhood immunisation in an urban area of Brazil. *J Epidemiol Commun Health* 1992;46:357–61.
- 10 Cutts FT, Rodrigues LC, Colombo S, et al. Evaluation of factors influencing vaccine uptake in Mozambique. *Int J Epidemiol* 1989;18:427–33.
- 11 Swain BK, Mishra S. Immunization coverage among migrant tribal children in slums of Orissa. *Indian Pediatr* 2006;43:1011–13.
- 12 Godfrey R, Julien M. Urbanisation and health. *Clin Med* 2005;5:137–41.
- 13 Yaméogo KR, Perry RT, Yaméogo A, et al. Migration as a risk factor for measles after a mass vaccination campaign, Burkina Faso, 2002. *Int J Epidemiol* 2005;34:556–64.
- 14 Hansen P. Long march, bitter fruit: the public health impact of rural-to-urban migration in the People's Republic of China. *Stan J East Asian Affairs* 2001;1:75–85.
- 15 Antai D. Migration and child immunization in Nigeria: individual- and community-level contexts. *BMC Public Health* 2010;10:116. <http://www.biomedcentral.com/1471-2458/10/116> (accessed 3 May 2014).
- 16 Amankwaa AA, Bavon A, Nkansah PT. Rural-urban migration and its effects on infant and child mortality in Ghana. *African Popul Stud* 2003;18:1–26.
- 17 Tam L. *Rural-to-urban migration in Bolivia and Peru: association with child mortality, breastfeeding cessation, maternal care, and contraception*. Demographic and health survey. Macro International Demographic and Health Surveys, 1994.
- 18 Hu Y, Li Q, Chen E, et al. Determinants of childhood immunization uptake among socio-economically disadvantaged migrants in east China. *Int J Environ Res Public Health* 2013;10:2845–56. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3734462/> (accessed 3 May 2014).
- 19 Oyo-lta A, Nwachukwu CE, Oranganje C, et al. Interventions for improving coverage of child immunization in low- and middle-income countries. *Cochrane Database Syst Rev* 2011;(7):Cd008145.
- 20 World Health Organisation (WHO). Global immunization data. 2014. [http://www.who.int/immunization/monitoring\\_surveillance/global\\_immunization\\_data.pdf](http://www.who.int/immunization/monitoring_surveillance/global_immunization_data.pdf) (accessed 3 May 2014).
- 21 World Health Organisation (WHO). Immunisation. 2014. <http://www.who.int/topics/immunization/en/> (accessed 3 May 2014).
- 22 Mavimbe J, Braa J, Bjune G. Assessing immunization data quality from routine reports in Mozambique. *BMC Public Health* 2005;5:108.
- 23 World Health Organisation. Immunisation coverage. 2014. <http://www.who.int/mediacentre/factsheets/fs378/en/> (accessed 30 Apr 2014).
- 24 World Health Organisation. MDG 4: reducing child mortality. 2013. [http://www.who.int/topics/millennium\\_development\\_goals/child\\_mortality/en/](http://www.who.int/topics/millennium_development_goals/child_mortality/en/) (accessed 3 May 2014).
- 25 Burton A, Lautenbach B, Gacic-Dobo M, et al. WHO and UNICEF estimates of national infant immunization coverage: methods and processes. *Bull World Health Organ* 2009;87:535–41. <http://www.who.int/bulletin/volumes/87/7/08-053819/en/> (accessed 12 May 2014).
- 26 The World Bank. New Country classification. 2014. <http://data.worldbank.org/about/country-and-lending-groups> (accessed 23 Jun 2014).
- 27 World Health Organisation. Training for mid-level managers (MLM) Module 7: the EPI coverage survey. 2008. [http://whqlibdoc.who.int/hq/2008/WHO\\_IVB\\_08.07\\_eng.pdf](http://whqlibdoc.who.int/hq/2008/WHO_IVB_08.07_eng.pdf) (accessed 12 May 2014).
- 28 Wilson EB. Probable inference, the law of succession and statistical inference. *J Am Statist Assoc* 1927;22:209–12.
- 29 National Population Commission (NPC) [Nigeria] and ICF Macro. *Nigeria demographic and health survey 2008*. Abuja, Nigeria: 2009. <http://dhsprogram.com/pubs/pdf/FR222/FR222.pdf> (accessed 12 Jul 2014).
- 30 United Nations Children's Fund (UNICEF). *2009 Coverage Evaluation Survey. Government of India, Ministry of Health & Family Welfare and UNICEF*. 2009. [http://www.unicef.org/india/National\\_Fact\\_Sheet\\_CES\\_2009.pdf](http://www.unicef.org/india/National_Fact_Sheet_CES_2009.pdf) (accessed 12 Jul 2014).
- 31 Centre for Health statistics and Information Ministry of Health. An analysis report of national health services in 2003 (Beijing: the Peking Union Medical College Press 2004), cited in Liu Y, Rao K, Wu J, Gakidou E. China's health system performance. *Lancet* 2008;372:1914–23. (accessed 12 Jul 2014).
- 32 Jian W, Chan KY, Reidpath DD, et al. China's rural-urban care gap shrank for chronic disease patients, but inequities persist. *Health Affairs* 2010;29:2189–96.
- 33 Keshri K, Prusty RJ. Migration and child health: exploring disparities in child nutrition and immunisation in urban India. Paper presented at: The XXVII International Population Conference of International Union for the Scientific Study of Population; 26–31 August 2013; Busan, Korea. [http://iussp.org/sites/default/files/event\\_call\\_for\\_papers/Full%20paper.pdf](http://iussp.org/sites/default/files/event_call_for_papers/Full%20paper.pdf) (accessed 17 May 2014).
- 34 Han K, Zheng H, Huang Z, et al. Vaccination coverage and its determinants among migrant children in Guangdong, China. *BMC Public Health* 2014;14:203. <http://www.biomedcentral.com/1471-2458/14/203> (accessed 20 May 2014).
- 35 Kusuma YS, Kumari R, Pandav CS, et al. Migration and immunization: determinants of childhood immunization uptake among socioeconomically disadvantaged migrants in Delhi, India. *Trop Med Int Health* 2010;15:1326–32. <http://www.ncbi.nlm.nih.gov/pubmed/20955496> (accessed 17 May 2014).
- 36 Tamoghna B, Mandal PK, Samarendra B. Assessment of health, nutrition and immunisation status amongst under-5 children in migratory brick kiln population of periurban Kolkata, India. *Sudanese J Public Health* 2011;6:7–13. <http://www.sjph.net.sd/files/Vol6N1/Original%20Article1.pdf> (accessed 17 May 2014).
- 37 Guo W, Feng Z, Diao L. Investigation of immunization status in children of floating population in Henan Province. *Zhonghua yu fang yi xue za zhi [Chin J Prev Med]* 2000;34:287–9. <http://www.ncbi.nlm.nih.gov/pubmed/11372398> (accessed 20 May 2014).
- 38 Huang X, Liu L, Chen P, et al. Measles vaccination status and related factors among infants in Ouhai district in Wenzhou city, Zhejiang province. *Disease Surveillance* 2011;26:815–17. <http://www.jbjc.org/EN/abstract/abstract7290.shtml> (accessed 17 May 2014).
- 39 Chhabra P, Nair P, Gupta A, et al. Immunization in urbanized villages of Delhi. *Indian J Pediatr* 2007;74:131–4. <http://medind.nic.in/icb/t07/i2/icbt07i2p131.pdf> (accessed 17 May 2014).
- 40 Sun M, Ma R, Zeng Y, et al. Immunization status and risk factors of migrant children in densely populated areas of Beijing, China. *Vaccine* 2010;28:1264–74. <http://www.ncbi.nlm.nih.gov/pubmed/19941996> (accessed 18 May 2014).
- 41 Hoshaw-Woodard S. *Description and comparison of the methods of cluster sampling and lot quality assurance sampling to assess immunization coverage*. WHO Department of Vaccines and Biologicals, 2001. [http://whqlibdoc.who.int/hq/2001/WHO\\_V&B\\_01.26.pdf](http://whqlibdoc.who.int/hq/2001/WHO_V&B_01.26.pdf) [accessed 17 Jun 2014].
- 42 Qian L, Yu H, Yanpeng Z, et al. Using the immunization information system to determine vaccination coverage rates among children aged 1–7 years: a report from Zhejiang Province, China. *Int J Environ Res Public Health* 2014;11:2713–28.
- 43 Kantayaporn T, Archavanitkul K, Peerapatnapokin W, et al. Expanded program on immunization (EPI) for children of Myanmar migrants living in Bangkok, Thailand. *J Popul Soc Stud* 2013;21:227–42.
- 44 Itimi K, Dienye P, Ordinoha B. Community participation and childhood immunization coverage: a comparative study of rural and urban communities of Bayelsa State, south-south Nigeria. *Niger Med J* 2012;53:21–5.
- 45 Canavati S, Plugge E, Suwanjatuporn S, et al. Barriers to immunization among children of migrant workers from Myanmar living in Tak province, Thailand. *Bull World Health Organ* 2011;89:528–31.
- 46 Islam MM, Azad KM. Rural-urban migration and child survival in urban Bangladesh: are the urban migrants and poor disadvantaged? *J Biosoc Sci* 2008;40:83–96.
- 47 Atkinson SJ, Cheyne J. Immunisation in urban areas: issues and strategies. *Bull World Health Organ* 1994;72:183–94.
- 48 Cutts FT. Strategies to improve immunization services in urban Africa. *Bull World Health Organ* 1991;69:407–14.
- 49 Mathew JL. Inequity in childhood immunization in India: a systematic review. *Indian Pediatr* 2012;49:203–23.
- 50 Amin R, De Oliveira T, Da Cunhab M, et al. Factors limiting immunization coverage in urban Dili, Timor-Leste. *Glob Health Sci Pract* 2013;1:417–27.
- 51 Tucker JD, Hao C, Zou X, et al. *The influence of migration on the burden of & response to infectious disease threats in China. A theoretically informed review*. The United Nations Research Institute for social development (UNRISD). 2013–3:1–25.
- 52 Peng ZQ, Chen WS, He Q, et al. Evaluation of the mass measles vaccination campaign in Guangdong Province, China. *Int J Infect Dis* 2012;16:e99–103.
- 53 Dietz V, Cutts F. The use of mass campaigns in the expanded program on immunization: a review of reported advantages and disadvantages. *Int J Health Serv* 1997;27:767–90.