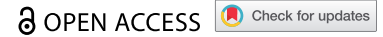


RESEARCH PAPER



# Vaccination coverage determinants in low uptake areas of China: a qualitative study of provider perspectives in Sichuan, Guangdong, and Henan Provinces

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## ABSTRACT

China's immunization programme is relatively strong, with latest WHO-UNICEF monitoring rates for 2019 showing national vaccination coverage over 90%. However, vaccination coverage is heterogeneous, varying across geographic regions, rural–urban communities, and sub-populations. We conducted a qualitative study from a critical realist perspective, analyzing semi-structured interviews with 26 vaccination providers in three provinces, selected to represent regional socioeconomic disparities across Eastern, Central, and Western China. We analyzed data thematically, using deductive and inductive coding. Providers reported vaccination coverage in their areas had increased significantly, but remained lower among migrant and left-behind children. Main coverage determinants were child-related (i.e. gender, number, health status), caregiver-related (i.e. socioeconomic status, role, education level, ethnicity), institution-related (i.e. vaccinator numbers, information system, appointment process), and system-related (i.e. vaccine supply, intersectoral cooperation, vaccine 'hesitancy'). Potentially effective measures to promote vaccination coverage included using routine maternal and child health-care visits for catch-up vaccination, providing additional health education, conducting follow-up family visits by village doctors, and requiring vaccination verification at school enrollment. This is the first qualitative study to examine potential determinants of low vaccination coverage in these areas of China. Findings can inform policies to strengthen the role of schools, develop the national immunization information system, and promote appointment apps. More consideration is needed to improve service quality and eliminating inequities, such as strengthening health education and service provision for migrant and left-behind children.

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## Introduction

Vaccination is a cost-effective public health strategy that has dramatically reduced childhood morbidity and mortality worldwide.<sup>1</sup> Vaccination coverage is a key predictor of infant mortality rates and reliable proxy indicator of primary health-care services availability.<sup>1</sup> An estimated 1.5 million deaths could be avoided if global vaccination coverage improved,<sup>2</sup> while research shows that vaccination coverage is threatened at multiple points, mediated by many stakeholders, throughout the vaccination process.<sup>3</sup> Factors affecting coverage include vaccination facilities accessibility, vaccination workforce availability and motivation,<sup>4</sup> funding,<sup>5</sup> vaccination facilities' environment,<sup>6</sup> vaccine quality – such as the vaccine scandal in Shandong province,<sup>7</sup> cold chain and storage,<sup>8</sup> surveillance,<sup>9</sup> and information management.<sup>10</sup> Service delivery factors, such as waiting time,<sup>11</sup> staff attitudes,<sup>12</sup> procedures,<sup>13</sup> follow-up, and health education,<sup>9</sup> influence quality and acceptability of services. When people choose to get vaccinated, health status,<sup>14</sup> demographics,<sup>15</sup> risk perceptions,<sup>16</sup> and costs can influence decision-making. Similarly, population migration, national

vaccine policy, media and public opinion<sup>17,18</sup> and socio-cultural norms<sup>19</sup> exert significant indirect influences on vaccination.

China's immunization programme started in 1978, and became the expanded programme of immunization (EPI) in 2007.<sup>20</sup> China's EPI is vertically integrated, operating through four centers for disease control (CDCs) levels<sup>20</sup> with over 100k public vaccination facilities.<sup>21</sup> The two vaccine categories in China include EPI vaccines, provided free to service-users by government, and non-EPI vaccines, which are purchased by service-users through the private sector.<sup>22</sup> EPI vaccines includes routine vaccines (i.e. Bacilli Calmette-Guérin vaccine [BCG], Inactivated Polio Virus vaccine [IPV3], Diphtheria Tetanus and Pertussis Vaccine [DTaP], Hepatitis B [HepB3] vaccine) and supplemental vaccines for mitigating outbreaks (e.g. Shanghai included varicella vaccine in 2018).<sup>23</sup> Latest WHO-UNICEF monitoring rates for 2019 show national routine vaccination coverage of over 90%.<sup>24</sup> However, coverage is heterogeneous across geographic regions, rural–urban communities, and sub-populations.<sup>25</sup> For example, Henan

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province has relatively low vaccination coverage, with 25% of counties and 18% of towns having coverage below 90% in 2015.<sup>26</sup>

Over the past decade, China achieved remarkable economic growth,<sup>27</sup> accompanied by mass population movement to urban areas where most work opportunities are found. The Sixth National Population Census in 2010, indicated a total of 36 million internally-migrant children, traveling for parents' work,<sup>28</sup> and 69 million 'left-behind' children staying with relatives when parents migrated for work.<sup>29</sup> Stratified statistics showed substantially lower coverage of five routine childhood immunizations (i.e. BCG, DTP, HepB, MCV, OPV) among migrant than host children, at 71.5–77.6% versus 98% respectively.<sup>27,30</sup> Moreover, timely coverage for all vaccines was less than 50%.<sup>28</sup> As migrant and left-behind children are significantly more likely to experience delayed or missed vaccine doses and higher disease incidence rates compared with host children,<sup>4</sup> improving vaccination coverage for these children is both challenging and necessary.<sup>31</sup>

Our study aimed to examine provider perspectives on vaccination status and coverage determinants in low-uptake areas of China. Objectives were to: (i) identify general vaccination status among low-uptake sub-populations; (ii) identify potential determinants and how they affect vaccination coverage; and (iii) summarize strategies for increasing vaccine uptake.

## Methods

### Study design and research question

We chose a qualitative (interpretive) design, informed by a critical realist perspective as described by Maxwell,<sup>19</sup> using semi-structured interviews with vaccination providers to explore their perceptions of vaccination coverage, coverage determinants in low-uptake areas, and effective practices for improving vaccination uptake. Qualitative methodologies are concerned with aspects of reality that cannot be quantified, focusing on examining and explaining complex social problems and dynamics through producing in-depth or illustrative data.<sup>32</sup> Critical realist approaches enable pragmatic engagement with 'real world' public health, to which concepts and theories refer.<sup>19</sup> This methodology is particularly appropriate for investigations such as this, in which perspectives are explored.

Our research question was: "What do providers consider to be the major factors contributing to reduced uptake of EPI vaccines in selected low-uptake provinces?"

### Study sites and recruitment

First, we selected three provinces in the south (Guangdong), middle (Henan) and west (Sichuan) of China to account for socioeconomic differences, regional characteristics, geographic location, and proportions of migrant and left-behind children. For example, Guangdong province has the greatest number of migrant children in China,<sup>33</sup> Henan province has among the highest proportion of left-behind children,<sup>34</sup> and Sichuan province has relatively high proportions of both left-behind and migrant children.<sup>35</sup> Second, due to dichotomous rural-urban health infrastructure in China, we randomly selected 1 rural

county and 1 urban district to represent each selected province. Third, in each county or district, we selected 2–4 vaccination facilities, including 1 rural public facility, 1 urban public facility, or 2 corresponding district/county-level CDCs. Finally, we purposively recruited 1–2 health-workers with responsibility for vaccination provision per facility.

### Data collection

We conducted semi-structured interviews from April to July 2019, using an interview guide we pre-tested in Shanghai at 1 rural and 1 urban public facility, 2 corresponding district/county CDCs, and Shanghai CDC. Topics included EPI vaccination coverage, determinants of vaccination coverage in low-uptake areas, and suggestions for improving vaccination uptake. Questions were open-ended to enable a broad range of answers and exploration of additional topics.

All interviews were conducted face-to-face in Mandarin by MS, XL, and XJ after obtaining written informed consent, lasted approximately forty minutes, and were audio recorded. Participants were given a small gift as a gesture of thanks. Anonymity was ensured by not including any personally identifiable information on audio or written transcripts and using numerical identifiers rather than names in all outputs (i.e., "G#" for Guangdong, "S#" for Sichuan, "H#" for Henan, plus 1-n for interview number). Confidentiality was ensured by conducting interviews at times and places selected by participants and storing all data in locked/password-protected files only accessible by the study team. Interviewers also compiled field notes on relevant information including interview environment, interviewee body language, and self-reflection, which helped inform analysis. Interviews were transcribed in Mandarin by the research team.

### Analysis

Transcripts and field notes were analyzed thematically in Mandarin, using NVivo 11 data management software (QSR International Pty Ltd, Victoria, Australia) and Braun and Clarke's six-stage thematic analysis approach with deductive and inductive coding.<sup>36</sup> First, three investigators (i.e., MS, TC, SL, SZ) read and became familiarized with the data. Second, investigators independently generated initial codes. Third, investigators developed a coding structure iteratively, collating codes related to status, determinants, and effective practices into preliminary themes, which were translated into English for discussion with non-Mandarin fluent coauthors. Investigators examined relationships between codes, focusing on the research question and objectives, then compiled them and summarized the content of each theme. Fourth, investigators conducted thematic mapping. Fifth, investigators refined and defined independent themes through discussion and further integration. Finally, all investigators reviewed and refined themes during reporting.

### Ethics

We obtained study approval from the Fudan University School of Public Health Medical Research Ethics Committee (IRB#2018-10-0701) and the London School of Hygiene & Tropical Medicine Observational Research Ethics Committee (reference 15965).

## Results

### Participant characteristics and themes

Table 1 shows characteristics of 26 providers interviewed. All (i.e. 18 facility EPI managers and 5 vaccinators from vaccination facilities, 3 CDC EPI managers) were from Sichuan (39%), Henan (35%), and Guangdong (27%) provinces. Most were women (65%) and most aged 20–39 (77%). Almost half (46%) had completed vocational college training or below, mainly in nursing (42%) and preventive medicine (23%).

Our three overarching themes were: (i) coverage issues in low-uptake groups; (ii) vaccination coverage determinants; and (iii) provider suggestions for improving vaccination uptake.

### Coverage issues in low-uptake groups

The main coverage issues described were low coverage among internal-migrant and left-behind children and unreliable vaccination coverage estimation. Most providers noted that the vaccination coverage rate in China increased from 70–80% to more than 90–95% in recent years, due primarily to increased parental awareness and government emphasize combined with enacting various practical measures such as mother classes and village doctors.

A dozen years ago, when we went to check vaccination coverage, we found a large number of children missing sugar pills [Oral Anti-Poliomyelitis Vaccine]. Now you cannot face such a situation anymore. Basically, parents are conscious of prevention now and we don't need to spend so much energy to explain. They come into our clinic of their own accord. G2

**Table 1.** Participant characteristics.

Provider characteristics	N (%)
Province	
Henan	9 (35)
Sichuan	10 (39)
Guangdong	7 (27)
Area	
Urban	11 (42)
Rural	15 (58)
Gender	
Male	9 (35)
Female	17 (65)
Age	
20–29 years	1 (4)
30–39 years	7 (27)
40–49 years	13 (50)
50–59 years	5 (19)
Education completed	
Secondary specialized school	4 (15)
Junior college	6 (23)
Undergraduate	5 (19)
Postgraduate	1 (4)
Other	10 (38)
Degree	
Clinical medicine	5 (19)
Nursing	11 (42)
Preventive medicine	6 (23)
Sanitary inspection	1 (4)
Chinese medicine	1 (4)
Missing	2 (8)*
Personnel cadre	
CDC EPI manager	3 (12)
Vaccination facility EPI manager	18 (69)
Vaccinator	5 (19)

\*Some participants were unwilling to disclose personal information.

However, providers noted there were still populations with poor vaccination coverage rates, primarily migrant and left-behind children whose coverage was about 5–15% lower (e.g. 80–90%) than that of host/non-left-behind children. Vaccination timeliness rates for left-behind children were also worse, often because grandparents did not receive health facility messages in time since these were sent to parents who might be far away or unable to communicate regularly. Vaccination management of migrant children was also described as challenging and their coverage as even lower than left-behind children.

The overall vaccination rate should be more than 90%. The vaccination rate for migrant children is relatively low, because it is difficult for us to reach them and remind their parents to bring them to our centre in time . . . G5

Most providers said the term “vaccination rate” was inaccurate and they preferred “reported vaccination rate,” as health information systems in most provinces were not interoperable and thus could not maintain a single unified national vaccination record per child. Vaccination rate was calculated using the total number of children vaccinated as numerator, and total estimated number of children of the relevant age-group as denominator, within a specified time-period and location. This estimation could be particularly inaccurate in provinces with high migration inflows or outflows.

The way we calculate vaccination rate, the denominator is not 100% exact, because you don't have the correct total population number [. . . Migrants] came for two or three months and leave the city. You just don't have that data . . . G2

### Vaccination coverage determinants

We developed a framework (Figure 1) organizing coverage determinants primarily related to the major stakeholders of vaccination including children, caregivers, providers/health facilities, systems&environment, and reported sub-themes accordingly below.

#### Children

Providers discussed three child-related coverage determinants: (i) gender; (ii) number; and (iii) health status.

Most providers described child gender as no longer a determinant of parental vaccination decision-making or behavior in contemporary China.

Now society is not like before. In the past, girls and boys were unequal. Now, we haven't faced a situation that they don't get vaccinated because they are girls. S9

Most providers indicated that the number of children had minimal effect on parents' vaccination behavior. However, they noted that some families with three or more children, and parents struggling to earn a living, were sometimes less able to complete children's vaccination. While rare, this reportedly occurred in Guangdong province and some ethnic minority areas.

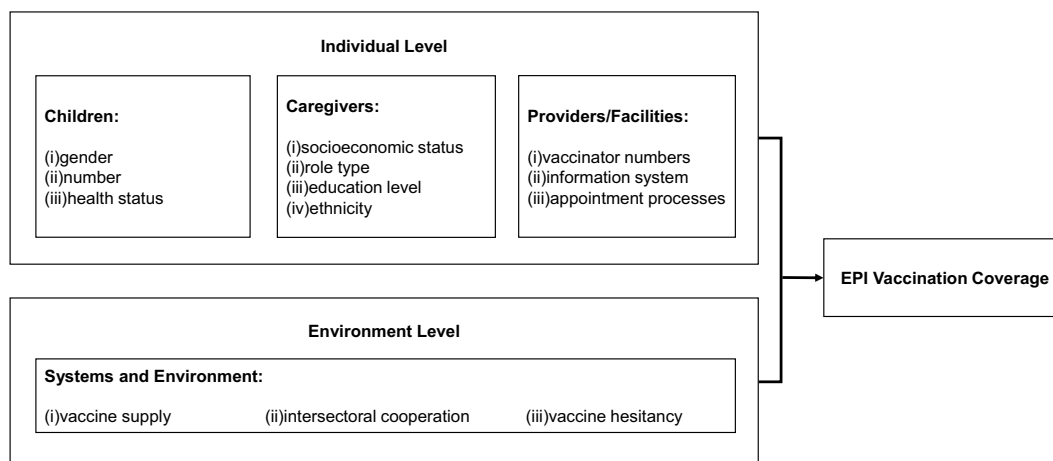


Figure 1. Conceptual framework.

About 3 years ago, a child got measles and he didn't get complete vaccination. We went to his home and found that his mother has three children. She said it was very difficult for her to raise the three children up. She was too tired to have extra energy to consider the immunization situation of children. G2

Many providers described child health status as an important determinant of timely vaccination. Parents often postponed vaccinations if their child was in poor health, such as having a cold or cough. Although this was a delay rather than rejection, some providers indicated this could affect vaccination rate calculations given the current calculation method.

### Caregivers

Providers discussed three caregiver-related coverage determinants: (i) socioeconomic status; (ii) role type; (iii) education level; and (iv) ethnicity.

Since EPI vaccines were government-funded, most providers said caregiver socioeconomic level would not affect their vaccination behavior. However, they indicated that wealthier parents were more inclined to choose imported or combined vaccines.

Now our EPI vaccines are all free. As for non-EPI vaccines such as varicella vaccine that parents think this kind of vaccine is good for their children, they will choose it. Most families don't care about one or two hundred yuan. G5

Some providers suggested that the type of caregiver mattered, with left-behind children having lower vaccination rates than children cared for directly by their parents. First, child vaccination cards were associated with parents' information, so all vaccination notices were sent to parents and this could cause delays.

Every time we send the vaccination messages from the system, we can only notify their parents. The parents are far away from their hometown, so that when grandparents know that they must bring their children to get vaccinated, it has already passed the prescribed time. H8

Second, providers suggested that older people often had insufficient scientific knowledge about vaccines and objective understanding of their benefits in preventing infectious diseases.

Many children here are cared for by grandparents. Grandparents still have traditional thoughts that they are still alive even though they haven't been vaccinated for so many years. Why would they bring their children to get vaccinated? H1

Most providers said that better educated parents were more likely to vaccinate their children, though not always. They suggested that parents who were better educated had a more scientific understanding of preventive healthcare than less educated parents.

Apparently, for example, if the child needs to get a pneumonia vaccine today, his parents with higher education will check all aspects of this vaccine clearly. Before vaccination, we will explain what the vaccine is and what children at this age need to be vaccinated. He immediately says 'You don't need to explain. I have already learned about it. We are here to get the pneumonia vaccine today. S3

However, a few providers in Guangdong and Sichuan provinces noted another trend emerging in recent years in which highly educated parents, usually with a masters or PhD, became increasingly less likely to vaccinate their children, citing concerns about the safety of domestic vaccines. It was common for such families to go to Hong Kong or other countries for vaccination.

Some parents here with high-level education received a lot of information. They have their own opinions about vaccination. Although they think vaccines are essential, they know more about the side effects and become more circumspect. Some parents who came to our clinic and found out that we didn't have imported vaccine, they would leave. G3

Providers in areas in which the Han Chinese dominant ethnicity was not the majority, such as along the Sichuan-Tibet border and areas in Guangdong province, indicated that ethnic minority children (e.g. Yi, Zang, Qiang) had lower vaccination rates than Han Chinese children, who are approximately 92% of the national population. Primarily, language barriers could prevent minority caregivers from communicating effectively with vaccination staff, which providers suggested meant they received inadequate health education.

It is obvious that some of the ethnic minorities, such as children from Yunnan province, resist vaccination. Their parents told us that their children were healthy and strong. Even though we persuaded them many times but it didn't work. G4

Secondly, minority religious beliefs about preventive health-care were less familiar to health-workers and they struggled to communicate the importance of vaccination to parents effectively.

They feel that if they get injections, the injections will take away their souls. Therefore, we must come to their home again and again for interpretation work. S2

However, providers suggested that when the proportion of minority families was very low, these families tended to adopt majority community norms and fulfil vaccination requirements more readily. Providers did not suggest why this might be.

### Providers/Facilities

Providers discussed three provider and facility-related coverage determinants: (i) vaccinator numbers; (ii) information system; and (iii) appointment processes.

Providers in urban areas of Guangdong and Sichuan provinces stated that relative to vaccination demands in their jurisdictions, vaccination staff numbers were insufficient, and indicated this made them tired of coping with vaccination work. Moreover, this led to neglect in managing follow-up files and omission checking, which affected local vaccination rates.

According to our schedule, we should have a noon break starting from 12 o'clock. But you see now it is around 12:30 pm. There are still a lot of chores. We have to finish all the vaccination work ... Too tired ... G6

Providers in Henan province and rural areas of Sichuan, however, stated that vaccination demands were not great and within the capacities of existing vaccination staff.

Most providers indicated that it was difficult to follow up the vaccination information of migrant children as China does not have a unified vaccination information system. Thus, when migrant children arrived in new areas, staff must reestablish vaccination files and manually supplement large amounts of information, which increased workloads.

The system is also not connected nationwide. For a place like us with lots of migrants, it is a pain. We need to re-register everyone without knowing their vaccination records. The workload is huge. G1

When migrant children moved, they seldom informed health facilities, and their files had to be kept, thus contributing to incorrect calculation of vaccination rate denominators.

On our information platform, we have some children who didn't come for vaccination for more than 3 months. When we called the parents, they said that they were outside, even if some of their children had been vaccinated in other healthcare centres, as the information could not be transferred, our vaccination rate was low. H5

Most vaccination facilities made appointments through manual registration, with appointment information recorded on paper, so parents could not be reminded effectively.

Additionally, this was not integrated with the facility triage queuing system, so people could not be triaged based on appointment. These gaps increased staff workload, lengthened waiting times, and contributed to facility crowding. Efforts to improve this, such as vaccination apps, had not yet been successful.

We have some vaccination apps like Xiaodoumiao. But these apps are not linked to the clinic's line-to-call system. Besides, the information cannot be updated in time. Despite our previous efforts to promote the app, more and more parents are reluctant to use it because it does not have these practical functions. S6

### Systems and environment

Providers discussed three system-related or structural coverage determinants: (i) vaccine supply; (ii) intersectoral cooperation; and (iii) vaccine hesitancy.

An adequate vaccine supply chain is prerequisite for effective and timely vaccination, and this was the primary systems determinant providers discussed. Most providers mentioned vaccine shortages occurring intermittently in their area, especially after the 2018 case of Changchun Changsheng Biotechnology Company providing substandard vaccines.<sup>37,38</sup> When EPI vaccine supplies were insufficient, children who should have been vaccinated could not be, which resulted in delayed and sometimes missed vaccination.

The shortage of vaccines is relatively more common after the vaccine incident. It used to be out of supply once every one or two months. We have to wait and will definitely have a low vaccination rate by the end of the year. G4

As a structural determinant, intersectoral engagement or its lack, was frequently mentioned, with providers most frequently suggesting stronger cooperation between health and education systems would improve vaccination rates. Most proposed vaccination inspections at school enrollment to find missed and under-vaccinated children. This cooperation was not currently mandatory, with no monitoring or evaluation indicators to encourage it, and cooperation thus depended on local inter-departmental relationships. Private schools particularly were less likely to provide assistance.

The national document doesn't stipulate that it is a responsibility of schools to check the vaccination verification before admission and to track their completion. In fact, schools, especially private schools, they care more about their own economic benefit than social benefit. If they admit more students who don't get complete vaccination, they could make more money. They don't care about the enforced rules. H3

Vaccine hesitancy is a growing global phenomenon, which providers described as mainly leading to short-term vaccination delays. Most mentioned that frequent recent vaccine incidents and lack of positive publicity had caused excessive negative public opinion.<sup>39,40</sup> Thus parents questioned the safety of vaccines, resulting in short-term reductions in vaccination uptake, and increasing staff workload in explaining the safety and benefits of vaccination for parents while vaccinating, which reduced efficiency.

After the vaccine incident, parents felt the vaccine was unsafe. They thought there would be fake vaccines, inferior vaccines, or expired vaccines. They suspected us and even didn't come to get vaccinated.

At that time, the flow of people for vaccination was one-third less than usual, but this time was relatively short, just about a month. After that special period, the person who came for the vaccination become more cautious but finally could accept our explanation. G1

### **Provider suggestions for improving vaccination uptake**

To help address concerns about low uptake, common provider recommendations related to four measures that had proven effective in areas in which they had been attempted: (i) using routine maternal and child healthcare visits for catch-up vaccination; (ii) providing additional health education; (iii) conducting blanket follow-up visits to all families assisted by village doctors; and (iv) vaccination verification at school enrollment.

Several providers suggested that routine maternal and child healthcare visits (e.g. postpartum visits or mothers classes) could be used effectively to ‘catch-up’ children who missed vaccinations and ensured more children were fully vaccinated. Some stated that they provided health education for pregnant women and reminded them of the vaccination schedule, which improved parental vaccination awareness and compliance.

The postpartum visit would definitely help the overall connection of the child’s vaccination work, telling her the importance of the child’s vaccination in the future, so that the parents wouldn’t ignore it. Child healthcare has the same effect, which is good for finding out the status of children who should get vaccinated. S1

A few also mentioned that it was more effective to track child vaccination and manage the ‘floating’ migrant population through complete maternal files.

Every month we have a mother’s classroom, and we give parents a clear introduction about each kind of vaccines and what diseases could be prevented. Then we make it clear which vaccines are paid or free, what are the conditions of the paid vaccines, and which vaccines are replaceable, such as hepatitis A that is inactivated and attenuated, and what the differences are between them. Finally, we tell them clearly from birth to how old the children should be vaccinated, what is the effect of our vaccination certificate. S7

Providers described many kinds of health education, including multimedia promotion, internet community management, and interpersonal instruction. They explained vaccination and answered questions during health education sessions and most indicated these sessions could greatly enhance parents’ awareness of vaccination, dispel parental worries, and improve responses to adverse events after vaccination, thereby improving vaccination uptake.

In terms of multimedia promotion, it can publish knowledge introductions, etc. It is that the public media should spread such positive news. I think this is very important. Because whether it is infectious diseases or planned vaccination, positive publicity is really something we lack. G2

We post some vaccine knowledge to the WeChat group. In this way, parents also knew what was going on with this vaccine and what side effects it would have. Let parents have a more positive and objective view of vaccination. G3

Providers checked the vaccination status of registered children through the child vaccination information system and identified all children who should be vaccinated per vaccine but had missed an appointment. Initially, providers texted or called

caregivers as quickly as possible with direct reminders. For children in remote areas, village doctors would contact households and even provided home vaccination services. These activities largely filled gaps and played a major role in catching up missed doses and improving vaccination rates among migrant children.

Every month we compile a list of children who didn’t get their vaccinations on time. The village doctor in charge of the village would get the list. Then they will visit door to door to notify those children. In return, the village doctors will be given corresponding subsidies through government public health funds, and the POV [vaccination facility] gives them two yuan or five yuan per child. H3

Preschools and primary schools could request to verify a child’s vaccination record before enrollment, with caregivers of children who are not fully vaccinated reminded to vaccinate as soon as possible. Schools that cooperated effectively with health facilities also conducted follow-up supervision, as providers reported that parents tended to listen to teachers more than to doctors though they did not have an explanation for why. Therefore, collaboration between vaccination facilities and schools was key to increasing vaccination rates among schoolchildren.

Schools’ collaboration is very important, even more effective than us. Parents are afraid of schools because they send their children there and they’re afraid. When schools tell them to get vaccinated, they will do it. G2

## **Discussion**

### **Key findings and implications**

This qualitative study is the first of which we are aware to explore vaccination coverage estimates and determinants, population disparities, and good practices to strengthen uptake in low-uptake areas in China. We found that vaccination coverage reportedly increased significantly, which was consistent with the epidemiological research literature.<sup>41,42</sup> Simultaneously, our study found 5–10% of children were incompletely vaccinated which means nearly 25 million children were not completely vaccinated for their age in China according to the 2020 census.<sup>43</sup> There are still some bottlenecks we couldn’t find by quantitative method.<sup>41</sup> This appeared partly due to rapid socioeconomic development and improvements in health awareness,<sup>44</sup> and services accessibility.<sup>45</sup> The lower reported vaccination coverage of internal-migrant and left-behind children, indicating vulnerabilities in national immune system, was also consistent with the literature on challenges for migrant children.<sup>46,47</sup> Ongoing urbanization, and related mass population movement,<sup>30</sup> has increased the numbers of internal-migrant and left-behind children. Elderly caregivers may delay vaccination<sup>46</sup> due to weak/slow information mechanisms and migrant families cannot readily use vaccination services due to frequent job/location changes and other barriers.<sup>47</sup> These realities put children at unnecessary risk<sup>46,48</sup> and should be addressed.

The significant recent increases in vaccination coverage reported are likely partially due to follow-up mechanisms such as through maternal and child health services, health

education initiatives, immunization information system-based follow-up assessments, and school admission checks. Existing research indicates the effectiveness of such measures.<sup>49–52</sup> The vaccination determinants we found corresponded with other research. For example, families with more children may divide resources and attention, so each child receives less.<sup>53</sup> Multiple children can divert caregivers' attention,<sup>14</sup> causing delayed<sup>14,54</sup> or missed vaccination.<sup>53,55,56</sup> As China's family planning policy has liberalized, starting with 'two-child policy' in 2016 and 'three-child policy' in 2021, multiple-child families will likely increase.<sup>57</sup> This suggests multiple-child families may require additional support in future to ensure complete vaccination coverage.

In general, when education status was below master's degree, better educated parents were normally more likely to vaccinate their children, which was consistent with other studies.<sup>49,58</sup> This could be because they better understood the benefits of vaccines, were more accepting of new ideas, and confident in deciding family health matters.<sup>59</sup> However, the coverage of parents with highest-education (e.g. master's degree or above) slightly decrease.<sup>60</sup> They had better access to both accurate and inaccurate vaccine-related information and could be more prone to vaccine hesitancy.<sup>37</sup> They also often had enough income to use the private sector or travel abroad for their preferred vaccinations. A US study found people with PhDs showed no decrease in Covid-19 vaccine hesitancy,<sup>61</sup> supporting our findings. This suggests that caregiver education affects vaccination uptake in differing ways and should be considered when targeting health education activities.

Ethnic minority families continued to have relatively low vaccination uptake, with other research confirming that caregiver ethnicity can be a barrier.<sup>62,63</sup> This may be due to religious and cultural norms, language,<sup>64</sup> or perceived biological differences (e.g. that they are more likely to have side effects).<sup>65</sup> This suggests additional efforts, and related formative research, are needed to support ethnic minority families to complete vaccination.

Immunization information system fragmentation across China, including lack of national networking and inter-provincial information sharing, has created multiple inefficiencies and data inaccuracies thus increasing workloads and vaccine duplication.<sup>66</sup> Some children, especially those who are unregistered, live in scattered or hard-to-reach areas and are frequently mobile, resulting in information gaps. When children's status changes (e.g. moving in/out, new address or phone), staff cannot access updated information in time.<sup>67</sup> Establishment of a national vaccine information system would help integrate disparate public health system resources,<sup>66</sup> quickly generate official vaccination records for schools, health departments, and vaccination providers,<sup>68</sup> and effectively track vaccination information for each child. This suggests the urgent need to establish and implement a truly national vaccination information system with cross-regional docking, so vaccination data can be accessed and shared nationwide.

Chinese and international research indicates that enrollment verification by the Health Department, in collaboration with the Education Department, can directly improve vaccination rates.<sup>69–72</sup> Such cooperation can enable children to be

accurately "tracked" for delayed or missed vaccination. Launch of the 2021 "Notice on Printing and Issuing the Inspection Measures for Children's Enrolment and Enrolment Vaccination Certificates,"<sup>73</sup> makes vaccination checks at school admission mandatory, clearly putting responsibility on schools to support vaccination, which should also improve rates among migrant and left-behind children. China has increasingly advocated for standardizing childhood vaccination. In 2016, China revised the *Regulations on The Administration of Vaccine Circulation and Vaccination*, emphasizing supplementary vaccination activities to ensure under/unvaccinated children were vaccinated. Gradual promotion of the "healthy integration into all strategies" concept in *Healthy China 2030*,<sup>74</sup> indicates the need to establish collaborative mechanisms between relevant departments to improve vaccination and therefore population health.

### Limitations

This study had several limitations. First, due to budget and time constraints, we only included a limited number of interviews in three low-uptake provinces and findings should be interpreted accordingly and not generalized. Second, while we included a range of provider cadres, we did not interview people in other departments or ministries (e.g. Finance), or include broader perspectives (e.g. vaccine manufacturers, caregivers, private providers), as we wished to focus on the perspectives of public-sector vaccination providers.

### Conclusions

This study explored vaccination provider perspectives of vaccination coverage estimates, population disparities, determinants, and good practices to strengthen uptake in low-uptake areas of China. Vaccination determinants related to children, caregivers, facilities/system, and environment, suggesting the need to emphasize supporting migrant, left-behind, multiple-child, and ethnic minority families; more targeting of health messaging by caregiver education; greater cooperation between vaccination programme, schools, and village doctors; and developing a national vaccine information system.

### Institutional review board statement

We obtained ethics approvals from the Medical Research Ethics Committee of the School of Public Health at Fudan University (reference IRB#2018-10-0701) and the Observational Research Ethics Committee of the London School of Hygiene & Tropical Medicine in the United Kingdom (reference 15965).

### Informed consent statement

Informed consent was obtained from all participants in this study.

### Data availability statement

Data presented in this study are available on reasonable request from the corresponding author.

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No potential conflict of interest was reported by the author(s).

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## Author contributions

Conceptualization, MS, TC, NH; Funding acquisition, TC, FYS, JZ, MS and NH; Investigation, JC, YC and MS; Methodology, SL, SZ, MS and NH; Project administration, MS and TC; Supervision, MS and TC; Validation, MS and NH; Data curation, SL and SZ; Formal analysis, SL and SZ; Writing original draft, SL, SZ and YC; Review and revisions, SL, SZ, TC, MS and NH. All authors have read and agreed to the published version of the manuscript.

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