Title: The determinants of vaccine hesitancy in China: a cross-sectional study following the Changchun Changsheng vaccine incident

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Highlights

- 60% of caregivers expressed some degree of hesitancy about vaccination in China.
- 26% accepted vaccination with doubts, 31% delayed and 3% refused some vaccines.
- Vaccine confidence was associated with a reduced odds of vaccine hesitancy.
- Knowledge of vaccine incidents had a significantly higher odds of vaccine hesitancy.
- More educated caregivers and Buddhists were more hesitant to vaccination.

Abstract

Introduction

Vaccine hesitancy is cited as one of top threats to global health. The Changchun Changsheng Biotechnology Company was found to have violated good manufacturing practices in July 2018, leading to widespread distribution of defective vaccines in China. We estimated the prevalence and determinants of vaccine hesitancy following the Changchun Changsheng vaccine incident (CCVI).

Methods

We conducted a cross-sectional survey in China in January 2019, and 2,124 caregivers of children <6 years old completed self-administered questionnaires. Multinomial logistic regression was used to assess the determinants of vaccine hesitancy; the potential determinants included demographics, socioeconomic status, vaccine confidence, and knowledge of the CCVI. Adjusted Odds Ratios (AORs) and 95% confidence intervals (CI) are reported.

Results

Around 89% of caregivers had heard of the CCVI. Although 83% and 88% of caregivers agreed that vaccines are safe and effective, respectively, 60% expressed some hesitancy about vaccination. Of those hesitant, 26% vaccinated their children at times with doubts, 31% delayed vaccination and 3% refused specific vaccines. Multinomial regression analysis showed that confidence in vaccine safety was associated with a reduced odds of doubts on vaccination (AOR = 0.64; 95%CI = 0.44-0.94), whereas caregivers who had heard of the CCVI had a significantly higher

odds of doubts on vaccination (AOR = 1.61; 95%CI = 1.05-2.45). Confidence in the vaccine delivery system and government were associated with a lower odds of vaccine hesitancy. Caregivers with higher education and Buddhism or other religions were significantly more hesitant to vaccinate their children.

Conclusion

Vaccine hesitancy was prevalent following the CCVI. Over half caregivers either accepted childhood vaccination with doubts or delayed vaccines; only a small number were active refusers. Our findings highlight the importance of addressing vaccine hesitancy, especially following vaccine incidents. Tailored communications are needed to reduce vaccine hesitancy, especially among the highly educated and Buddhist caregivers.

Keywords: Vaccine, confidence, hesitancy, acceptance, vaccine incident, vaccine crisis, China.

Introduction

Vaccination is often cited as one of the most effective achievements of public health to prevent infectious diseases. However, this success is being challenged by individuals and groups with negative attitudes toward immunization and those who may choose to delay or refuse vaccines [1-3]. Over the past decades, reluctance concerning vaccination has proliferated, and vaccine hesitancy has grown into an issue warranting global attention [4, 5]. In 2012 the World Health Organization (WHO) Strategic Advisory Group of Experts (SAGE) on Immunization established a 'Working Group on Vaccine Hesitancy', and in 2019 vaccine hesitancy was cited by WHO as one of the top ten threats to global health [6].

Vaccine hesitancy can be defined as "delay in acceptance or refusal of vaccination despite the availability of vaccination services" [7] and covers a continuum of individuals who accept all vaccines with doubts to those who completely refuse vaccines [8]. Vaccine hesitancy is a complex and context specific issue that varies across time, place, and vaccines [7]. Studies that have estimated the prevalence and drivers of vaccine hesitancy indicate different levels of vaccine hesitancy across countries. For example, the prevalence of vaccine hesitancy was 31.8% in the US (2014) [9], 45.8% in France (2016) [5], 24.6% in Italy (2017) [2], 23.0% in Brazil (2016) [10] and 11.6% in Malaysia (2016) [11]. Vaccine hesitancy appears to be more prevalent in developed countries than developing countries. According to the SAGE Working Group, vaccine hesitancy is determined by contextual (e.g., culture, gender,

socio-economic group and geographic barriers), individual and social or group influences (e.g., belief, attitudes, knowledge and experiences with vaccination), and vaccine and vaccination-specific issues (e.g., costs, mode of administration and delivery) [3].

China initiated its Expanded Program of Immunization (EPI) in 1978 [12]. Coverage of EPI vaccines has consistently been over 90% in the last decade, but the coverage of non-EPI vaccines is lower [13]. Many vaccine incidents such as psychogenic reactions associated with a school-based hepatitis A vaccination campaign in Anhui province in 2005 [14], media reports of child deaths or disability following vaccination in Shanxi province in 2010 [15], coincidental infant deaths following hepatitis B vaccination in 2013 [16], and the illegal sale of vaccines in Shandong in 2016 [17] have occurred in the recent past. The most recent vaccine-related incident involved the Changchun Changsheng Biotechnology Company, which was found to have violated the Good Manufacturing Practice standards in manufacturing diphtheria, pertussis, and acellular tetanus (DTaP) vaccines and rabies vaccines in July 2018 [18]. A total of 499,800 doses of substandard DTaP vaccines were produced and entered the market [18]. Vaccine incidents have the potential to raise public concern and doubts about vaccination. Studies have shown that the hepatitis B vaccine incident in 2013 significantly decreased parental confidence in childhood vaccines [19], and the Shandong vaccine incident reduced uptake of both childhood and adult vaccines [17].

Estimates of the prevalence of vaccine hesitancy among Chinese caregivers are sparse and are especially important in the light of the Changchun Changsheng vaccine incident (CCVI) [3]. Previous studies in China have focused on the influence of individual-level knowledge, attitudes and beliefs on vaccination behavior [16-19]. Besides individual-level factors, vaccine hesitancy is also known to be influenced by contextual and social or group influences, which are often understudied. A few older studies have attempted to quantify the effect of the CCVI on vaccine confidence, reporting reduced public trust in vaccines following the CCVI [18,20-23]. Our study aimed to provide updated estimates of the prevalence of vaccine hesitancy following the CCVI, and to assess the determinants and reasons for vaccine hesitancy among Chinese caregivers.

Methods

Study design and data collection

We conducted a cross-sectional survey in January 2019, six months after the CCVI. Data was collected in the Shenzhen megacity in Guangdong province, Anhui province and Shaanxi province, located in the East, Middle and West areas of China, respectively. We selected one urban district and one rural county in Anhui and Shaanxi provinces, and one urban district in Shenzhen megacity. The caregivers (parents or guardians) of children <6 years old were enrolled through a two-stage, cluster sampling process. In each district/county, 3-4 communities were selected to represent lower, middle and higher socio-economic population strata. In each

community, caregivers were recruited from a vaccination clinic (for children aged <3) and a kindergarten (for children aged 3-6). Caregivers of all children visiting the sampled vaccination clinics on a given day during the survey period and from a class in the sampled kindergarten were invited to participate in our survey.

The questionnaire was pilot tested among 30 participants in a non-study community. There was a consent statement at the start of the questionnaire, and if respondents were willing to proceed, they could complete the questionnaires, either by themselves on their mobile phone or in writing on the spot with assistance from an interviewer. It took approximately 10 minutes to complete the self-administered questionnaire and respondents received electronic currency as a token of participation worth 5 Chinese Yuan (0.7 USD). The study was approved by a university ethics committee.

A total of 2,178 caregivers were invited to participate in the survey, and 2,168 completed questionnaires, including 1,870 online questionnaires and 298 paper-based questionnaires. Of these, 43 questionnaires with a completion time of <2 minutes and one questionnaire with missing data were excluded from the analyses. We used 2 minutes as a cutoff point as it was the least possible time determined during pilot-testing to complete the questionnaires. Data from 2,124 participants were included in the analyses, resulting in a response rate of 97.5%.

Measures

Vaccine hesitancy

This article focuses on understanding vaccine hesitancy and its determinants, and our previous article explored the issue of vaccine confidence [24]. We used the following questions (Table 1) to measure vaccine hesitancy as defined by SAGE: "have you ever hesitated, delayed, or refused about getting a vaccination for your child or yourself due to reasons other than allergies and sickness?" These questions measured both current vaccination status and past experiences with vaccination, and caregivers were classified into four categories based on their responses to these questions. Caregivers who had not delayed, refused or had no doubts about vaccinating their children were categorized "no vaccine hesitancy"; those who had not delayed or refused a vaccination for their child but accepted it with doubts were "acceptors with doubts"; those who had delayed but not refused a vaccination for their children were "delayers"; and those who had refused at least one vaccination for their children were "refusers".

Vaccine confidence

Vaccine confidence is considered an important factor influencing vaccine hesitancy. According to the "3Cs" model of vaccine hesitancy proposed by the WHO EURO Vaccine Communications Working Group, confidence, convenience, and complacency are important predictors of vaccine hesitancy [25]. In this model, vaccine confidence includes three dimensions of trust: 1) trust in the effectiveness and safety of vaccines; 2) trust in the system that delivers them, including the reliability

and competence of the health services and health professionals; and 3) trust in the motivations of the policy-makers who decide on the needed vaccines [8]. In our study, the current status of vaccine confidence, including trust in vaccines, the vaccine delivery system and the government, were measured by eight items (Table 1) [8]. Trust in vaccines was measured by the extent to which caregivers agreed with the following four items on a five-point Likert scale: importance, safety, effectiveness, and religion compatibility of vaccines [26]. Responses to the four items were grouped into two categories: disagree (including "strongly disagree", "tend to disagree" and "neutral or don't know") and agree (including "strongly agree" and "tend to agree") for the purpose of data analysis. To measure trust in the vaccine delivery system, we built a trust score by summing the degree of trust in healthcare providers, professional institutions and vaccine manufacturers – the degree of trust was coded from 1 indicating strong distrust to 5 for strong trust [5]. Moreover, responses to trust in the government (policy-makers) were dichotomized: distrust (including "strongly distrust", "distrust" and "neutral") and trust (including "strongly trust" and "trust").

Demographic characteristics and socioeconomic status

The demographic characteristics collected included province (Shenzhen, Anhui or Shaanxi), rural or urban area, caregiver's relationship with children (mother, father, grandparents or others), age, and religious beliefs (none, Buddhism or others). The assessment of socioeconomic status included questions on education (middle school or below, high school, junior college, bachelor degree or above), annual household

income (<20, 20-50, 50-100, 100-200 or >200 thousand -Renminbi- RMB), and residence registration (local resident or internal migrant).

Reasons for vaccine hesitancy

Based on the 3C's model [25] and the Parent Attitudes about Childhood Vaccines questionnaire [2], we selected 12 questions to explore caregivers' reasons for vaccine hesitancy, which covered five domains: complacency, confidence, convenience, information or experience, and fears of needles. Only caregivers categorized as vaccine hesitant were required to answer these 12 questions.

Statistical analysis

Data from the online questionnaires were entered and uploaded to the Wenjuanxing online platform (https://www.wjx.cn/) in real-time, and data from the paper-based questionnaires were double-entered using Epidata 3.1. The prevalence of vaccine hesitancy was measured as the percentage of refusers, delayers, acceptors with doubts, and those with no vaccine hesitancy in the total study sample. Univariate analyses were performed to compare the levels of vaccine hesitancy by participants' demographic characteristics and vaccine confidence, using Chi-square or Fisher's exact tests (if expected frequency <5) for categorical measures and ANOVA for continuous measures. Multinomial logistic regression was used to estimate the determinants of vaccine hesitancy, with "no hesitancy" used as the reference group for comparisons. The determinants investigated included caregivers' demographic

characteristics, socioeconomic status, vaccine confidence, and knowledge of the CCVI. All variables with $p<0.05$ in the univariate analyses were added into the multinomial logistic regression model. Data were analyzed using the Stata software, version 14. Adjusted Odds Ratios (AORs) and 95% confidence intervals (CI) are reported.

Results

Participant characteristics

Caregivers' social demographic characteristics are presented in Table 2. The average age of caregivers was 34 years old (standard deviation = 7.6), 61.0% of caregivers lived in urban areas, and 71.1% were mothers. Around one-third (35.1%) had a bachelor degree or higher education, 18.6% were internal migrants, and 7.8% reported having a religious faith, predominantly Buddhism.

Vaccine confidence and hesitancy

A significant majority (96.0%) of caregivers agreed that vaccines are important for children with 82.7% and 88.2% agreeing that vaccines are safe and effective, respectively. The average score for trust in the immunization delivery system was 12 (out of 15), and 81.5% of caregivers expressed trust in the government. Despite these high levels of confidence, 60.0% caregivers of all participants expressed some degree of hesitancy towards vaccination. Of these, 26.2% were 'acceptors with doubts', 30.7% 'delayers' and 3.0% 'refusers' (Table 3).

The determinants of vaccine hesitancy

Table 2 and 3 show the univariate associations between vaccine hesitancy and respondents' socio-demographic characteristics and their vaccine confidence. The prevalence of vaccine hesitancy varied significantly by socio-demographic characteristics such as rural or urban area, caregiver relationship with children, caregivers' age, religion, education, and income. Vaccine hesitancy was negatively associated with caregivers' confidence in vaccines (importance, safety and effectiveness), the vaccine delivery system, and the government. The prevalence of vaccine hesitancy was significantly higher among those who heard of CCVI compared with those had not heard of the CCVI (61.2% vs. 50.6%). Province, registered residence (internal migrants or not), and religious compatibility towards vaccination did not have significant univariate associations with vaccine hesitancy and were not included in the multinomial logistic regression analysis.

Table 4 presents the determinants of vaccine hesitancy from the multinomial logistic regression models, with "no vaccine hesitancy" used as the reference group for comparisons. This analysis showed that caregivers aged 30-35 years (compared to those < 30 years) had a significantly higher odds of being acceptors with doubts (AOR = 1.48; 95%CI = 1.14-1.91) and delayers (AOR = 1.37; 95%CI = 1.08-1.76) relative to the no vaccine hesitancy category. Caregivers with Buddhism or other religious belief (compared to no religion) had a higher odds of being acceptors with

doubts (AOR = 1.78; 95%CI = 1.16-2.73), delayers (AOR = 1.50; 95%CI = 0.99-2.26) or refusers (AOR = 2.52; 95%CI = 1.11-5.72), and caregivers with higher education had a significantly higher odds of being acceptors with doubts (relative to the no hesitancy group). Rural or urban area, caregivers' relationship with children, and income level did not have significant associations with vaccine hesitancy in the analysis. In addition, confidence in the safety of vaccines was negatively associated with being an acceptor with doubts (AOR = 0.64; 95%CI = 0.44-0.94), however, caregivers who heard about the CCVI had an increased odds of being acceptors with doubts (AOR = 1.61; 95%CI = 1.05-2.45). Confidence in the vaccine delivery system and government were also negatively associated with vaccine hesitancy.

Reasons for vaccine hesitancy

The main reasons for vaccine hesitancy reported by caregivers (Table 5) were hearing or reading negative information about vaccines (62.2%) or having a bad experience with previous vaccinations for their children (25.3%). Other important reasons included caregiver concerns about vaccine safety (24.6%), children's fear of needles (20.6%), complacency regarding vaccine-preventable diseases (20.5%), and the cost of self-paid vaccines (19.6%). Loss of confidence, inconvenience (including timing and cost), and negative vaccination experiences were significantly more frequently reported by 'refusers' compared with 'acceptors with doubts' or 'delayers'.

Discussion

We investigated the prevalence of vaccine hesitancy and its determinants from data collected in three provinces of China. Approximately 60% of caregivers of children <6 years old were hesitant about vaccinating their children. Hearing of the CCVI and lower confidence in the safety of vaccines, the vaccine delivery system, and the government were associated with odds of being vaccine hesitant. More educated caregivers and those reporting Buddhism or other religious beliefs were also significantly more hesitant toward vaccination.

Our study found that in China, 60% of caregivers experienced some degree of vaccine hesitancy six months after the CCVI. The proportion of delayers and refusers (33.7%) in our study was similar to the estimate from Guangzhou, China, in March 2020 (33.04%) [23], but higher than estimates from other countries such as Brazil, Malaysia, US, Italy, France [2,5,9-11]. The higher proportion of vaccine hesitant caregivers relative to other countries may be due to our survey being conducted within six months of the CCVI. Previous CCVI-related studies found that public confidence in vaccines decreased and their trust in government was eroded after the CCVI [18,20-22]. Our findings show that, reduced vaccine confidence and trust in government can lead to increased vaccine hesitancy among Chinese caregivers (Table 4). And hearing about CCVI was associated with a significantly increased odds of vaccine hesitancy, which concurs with an earlier study following the CCVI [23]. In addition, the patterns of vaccine hesitancy in China were different from other countries. In our study, most vaccine-hesitant caregivers were either ‘delayers’

(30.7%) or ‘acceptors with doubts’ (26.2%), rather than ‘refusers’ (3.0%). The proportion of delayers in China was much higher than that in Malaysia (7.9%) [11], France (7%) [5], US (7.3%) [9] and Ghana (22%) [27], but the proportion of refusers was much lower in our study than these countries: the prevalence of refusers was 3.2% in Malaysia [11], 15% in Ghana [27], 26% in France [5], and 5.6% in the US [9]. In China, EPI vaccines are provided free of charge and receiving them on time is a requirement for school admission; there are no exemptions regarding personal philosophical or religious beliefs. Hence, few caregivers would outrightly refuse vaccines for their children, but may instead delay or accept vaccinations with doubts due to this policy.

We reported that having confidence in the safety of vaccines was associated with a significantly reduced odds of being an acceptor with doubts, and concerns about the safety of vaccines were listed as one of the main reasons for Chinese caregivers’ hesitancy towards vaccinating their children. These findings are consistent with other studies around the world [28,29]. If the perceived risk of vaccine-preventable diseases is lower than the perceived risk from vaccines, caregivers are likely to doubt the value of vaccines and become vaccine-hesitant [30]. Many studies suggest that a skewed risk-benefit perception favoring vaccine risk is a common reason for vaccine hesitancy [28,31]. In addition, we found that confidence in the vaccine delivery system and government significantly was associated with vaccine hesitancy - higher levels of confidence were associated with a reduced odds of doubt, delay or refusal to

vaccinate. The vaccine delivery system and government are important sources of vaccine-related information for the public and play key roles in addressing vaccine hesitancy. After the CCVI, the spread of negative information about vaccines through the media was overwhelming and weakened public's confidence in vaccine safety, vaccine delivery system, and the government [18]. In our study, exposure to negative information was the top reason for vaccine hesitancy (Table 5) and hearing about CCVI significantly increased the odds of being an acceptor with doubts (Table 4), which corresponds with findings from other studies [2,32]. Therefore, efforts should be made to address public's concern of vaccine safety, and to rebuild confidence in the vaccine delivery system and government following the vaccine incidents. One effective way is to improve health education to caregivers by delivering accurate and timely information about childhood vaccines to increase public confidence and consequently decrease vaccine hesitancy.

An important finding from our survey is that high levels of caregiver vaccine hesitancy can co-exist alongside high vaccine confidence. In our study, 60% of caregivers expressed some degree of hesitancy about vaccination, whereas 82.7% and 88.2% perceived vaccines to be safe and effective, respectively. There may be two possible reasons to explain this inconsistency. Firstly, caregivers may have reported their hesitancy towards specific vaccines, while their confidence might reflect their attitudes towards vaccination in general. Vaccine hesitancy may link specifically to vaccines involved in the CCVI, and vaccine confidence may have been reported for

the other EPI vaccines which have been in use decades. Secondly, according to the "3Cs" model of vaccine hesitancy, vaccine hesitancy covers confidence in vaccines as well as convenience (access to vaccination) and complacency (regarding the risk of vaccine preventable diseases) [25]. In our study, confidence issues, inconvenience (including timing and cost), and complacency issues were listed as reasons for vaccine hesitancy by a fifth (20%) participants, whereas more than half (62%) of caregivers listed exposure to negative vaccination information as their reason for vaccine hesitancy. This indicates that exposure to negative information, a loss of confidence in vaccine, inconvenience of getting vaccinated, and complacency issues all contributed to high levels of vaccine hesitancy in China. Furthermore, we found that refusers reported confidence issues, inconvenience, and negative vaccination experiences more frequently than acceptors with doubts or delayers (Table 5).

Interestingly, a positive trend between education level and accepting vaccination with doubts was observed in our study, although the odds of delaying or refusing vaccines did not significantly vary by education level. The association between education level and vaccine hesitancy varies in different contexts [33]. In France, highly educated parents were more likely to be delayers or refusers than non-hesitant [5], but no significant association was observed in Malaysia and Australia [11,32]. Caregivers with higher education may have better access to and search for vaccine-related information, and thereby be exposed to more negative vaccination information. Hence, they may be more prone to having doubts about vaccines for their children. A

negative association between education level and confidence in vaccine delivery system was also observed for caregivers in our study. On the other hand, caregivers with higher education are more rational and critical instead of emotional and heuristic in their decision making [5,33]. Although more exposed to negative information, caregivers with higher education levels also have a higher awareness of the value of vaccines. Therefore, even with doubts about vaccination, caregivers' doubts were not serious enough to make them delay or refuse vaccines for their children. Following the vaccine incidents, vaccination communication should be promoted to address the doubts about vaccination, especially targeting caregivers with higher education levels.

Reporting a religious affiliation was also a predictor of vaccine hesitancy in this study. In China, most people have no religious beliefs, and a minority are Buddhists. Our results showed that Chinese caregivers who were Buddhist or had other religious beliefs had a higher prevalence at each level of vaccine hesitancy compared to those who did not report a religious belief. Globally, the proportion of residents reporting religious incompatibility to vaccines is known to be the highest (25%) in the South-East Asian and Western Pacific regions where Buddhism is widespread [26]. Also, a European vaccine confidence survey suggested that Muslims are much less likely to agree that vaccines are safe and effective compared to Atheists [34], and a lower proportion of fully immunized children to Muslim mothers (compared with Christian mothers) has been reported in a Nigerian study [35]. More research is needed to explore the reasons why some Buddhists in China may potentially consider

vaccination as incompatible with their religious beliefs.

There were some limitations in our study. Firstly, the questionnaires were self-administered, which may have led to a misunderstanding of some questions. However, this anonymous online method of questionnaire administration addressed possible concerns of response bias due to participant fears of being criticized based on their perceptions towards childhood vaccination. Secondly, there may be some selection bias due to our sampling methodology. Participants were recruited via vaccination clinics, and caregivers who take their children to clinics for vaccination may be less likely to have vaccine hesitancy than those that do not present at the clinics. Therefore, the prevalence of vaccine hesitancy may actually be underestimated in our study. Thirdly, the small sample size of the "refusers" group (n=64) may have reduced the power to detect differences between the refusers relative to the no hesitancy group. Finally, we did not ask caregivers about their hesitancy towards specific childhood vaccines, and hesitancy level may vary by vaccines. The impact of the vaccine incident may last for a long time, and therefore, we plan to conduct a follow-up survey in late 2020 to describe the trend of vaccine hesitancy following the CCVI using estimates from this survey as a baseline.

Conclusions

Vaccine hesitancy was prevalent among Chinese caregivers of young children following the CCVI. Over half of caregivers in our study either accepted childhood

vaccination with doubts or delayed vaccination; only a small number were active refusers. Our findings highlight the importance of addressing vaccine hesitancy, especially following vaccine incidents. Tailored communications are needed to reduce vaccine hesitancy, especially among the highly educated and Buddhist caregivers. Timely, effectively and appropriately disseminating vaccine safety information to the public is crucial to ensuring public trust in childhood vaccines.

Author Contributions

ZH led the study design, guided the data analysis, and co-wrote the manuscript. FD analyzed data and wrote the manuscript. TC co-led the study design and revised the manuscript. MF revised the manuscript. FYS, XZ, KH, LR, HY participated in the study design. ST, HL co-led the study design and reviewed the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval

The Fudan University School of Public Health, and the London School of Hygiene & Tropical Medicine Ethics committees approved the study protocol [FDU IRB#2018-10-0703, LSHTM Ethics Ref 16016].

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Table 1. Measures of vaccine hesitancy and confidence.

Measures
Vaccine hesitancy (3 items)
1. Have you ever hesitated about getting a vaccination for your child or yourself due to reasons other than allergies and sickness? (Yes/No)
2. Have you ever delayed getting a vaccination for your child or yourself due to reasons other than allergies and sickness? (Yes/No)
3. Have you ever refused to get a vaccination for your child or yourself due to reasons other than allergies and sickness? (Yes/No)
Vaccine confidence (3 dimensions of trust)
Degree of trust in vaccines (4 items)[a]
1. Vaccines are important for children to have
2. Overall, I think vaccines are safe
3. Overall, I think vaccines are effective
4. Vaccines are compatible with my personal or religious beliefs
Degree of trust in system that delivers vaccines (3 items)[b]
Please estimate your degree of trust in the following sources regarding vaccination information and services they provided.
1. Healthcare providers
2. CDC, hospitals or other professional institutions
3. Vaccine manufacturers and companies
Degree of trust in motivations of the policy-makers who decide on the needed vaccines (1 item)[b]
Please estimate your degree of trust in government regarding vaccination information it provided.

[a] 5-point Likert scale from strongly disagree to strongly agree, including neutral/don't know.

[b] 5-point Likert scale from strongly distrust to strongly trust, including neutral.

Table 2. Participants' characteristics and vaccine hesitancy level, n(%).

Characteristics	Total sample	Vaccine hesitancy level				p-value
		No vaccine hesitancy	Acceptors with doubts	Delayers	Refusers	
Total	2124	850 (40.0)	557 (26.2)	653 (30.7)	64 (3.0)	-
Province						
Shenzhen city	411 (19.4)	168 (40.9)	99 (24.1)	130 (31.6)	14 (3.4)	0.829[a]
Anhui province	855 (40.3)	344 (40.2)	231 (27.0)	252 (29.5)	28 (3.3)	
Shaanxi province	858 (40.4)	338 (39.4)	227 (26.5)	271 (31.6)	22 (2.6)	
Urban or rural area						
Urban	1295 (61.0)	491 (37.9)	353 (27.3)	420 (32.4)	31 (2.4)	**0.006**[a]
Rural	829 (39.0)	359 (43.3)	204 (24.6)	233 (28.1)	33 (4.0)	
Caregiver relationship with children						
Mother	1511 (71.1)	563 (37.3)	386 (25.6)	518 (34.3)	44 (2.9)	**<0.001**[a]
Father	421 (19.8)	167 (39.7)	138 (32.8)	100 (23.8)	16 (3.8)	
Grandparents and others	192 (9.0)	120 (62.5)	33 (17.2)	35 (18.2)	4 (2.1)	
Age group (years)						
<=30	766 (36.1)	317 (41.4)	189 (24.7)	230 (30.0)	30 (3.9)	**<0.001**[b]
~35	853 (40.2)	279 (32.7)	254 (29.8)	299 (35.1)	21 (2.5)	
~40	267 (12.6)	109 (40.8)	68 (25.5)	83 (31.1)	7 (2.6)	
>40	238 (11.2)	145 (60.9)	46 (19.3)	41 (17.2)	6 (2.5)	
Religious beliefs						
None	1958 (92.2)	802 (41.0)	504 (25.7)	596 (30.4)	56 (2.9)	**0.015**[a]
Buddhism or others	166 (7.8)	48 (28.9)	53 (31.9)	51 (34.3)	8 (4.8)	
Education						
Middle school or below	391 (18.4)	191 (48.9)	51 (13.0)	137 (35.0)	12 (3.1)	**<0.001**[a]
High school	412 (19.4)	190 (46.1)	90 (21.8)	126 (30.6)	6 (1.5)	
Junior college	575 (27.1)	200 (34.8)	178 (31.0)	179 (31.1)	18 (3.1)	
Bachelor degree or above	746 (35.1)	269 (36.1)	238 (31.9)	211 (28.3)	28 (3.8)	
Annual household income (1000 Renminbi)						
<20	296 (14.0)	125 (42.2)	65 (22.0)	93 (31.4)	13 (4.4)	**0.018**[a]
20-50	425 (20.0)	189 (44.5)	93 (21.9)	128 (30.1)	15 (3.5)	
50-100	619 (29.2)	234 (37.8)	165 (26.7)	201 (32.5)	19 (3.1)	
100-200	479 (22.6)	201 (42.0)	139 (29.0)	130 (27.1)	9 (1.9)	
>200	303 (14.3)	100 (33.0)	94 (31.0)	101 (33.3)	8 (2.6)	
Registered residence						
Local residents	1729 (81.4)	685 (39.6)	456 (26.4)	528 (30.5)	60 (3.5)	0.071[a]
Internal migrants	395 (18.6)	165 (41.8)	101 (25.6)	125 (31.7）	4 (1.0)	

[a] P value from Chi-square. [b] P value from Fisher's exact tests. Boldface indicates statistical significance (p<0.05).

Table 3. Participants' vaccine confidence and vaccine hesitancy level, n(%).

Vaccine confidence	Total sample	Vaccine hesitancy level				p-value
		No vaccine hesitancy	Acceptors with doubts	Delayers	Refusers	
Total	2124	850 (40.0)	557 (26.2)	653 (30.7)	64 (3.0)	-
Trust in vaccine importance						
Disagree	80 (3.8)	23 (28.8)	23 (28.8)	28 (35.0)	6 (7.5)	**0.034**[a]
Agree	2043 (96.2)	827 (40.5)	534 (26.1)	624 (30.5)	58 (2.8)	
Trust in vaccine safety						
Disagree	368 (17.3)	98 (26.6)	125 (34.0)	126 (34.2)	19 (5.2)	**<0.001**[b]
Agree	1755 (82.7)	752 (42.9)	432 (24.6)	526 (30.0)	45 (2.6)	
Trust in vaccine effectiveness						
Disagree	250 (11.8)	73 (29.2)	75 (30.0)	88 (35.2)	14 (5.6)	**<0.001**[b]
Agree	1870 (88.2)	776 (41.5)	481 (25.7)	563 (30.1)	50 (2.7)	
Religious compatibility						
Disagree	88 (4.2)	32 (36.4)	24 (27.3)	26 (29.6)	6 (6.8)	0.211[a]
Agree	2034 (95.9)	818 (40.2)	533 (26.2)	625 (30.7)	58 (2.9)	
Score of trust in system that delivers vaccines (mean ± Standard deviation)	11.97 ± 1.95	12.42 ± 1.82	11.58 ± 1.96	11.77 ± 1.95	11.30 ± 2.28	**<0.001**[c]
Trust in government						
Distrust	392 (18.5)	98 (25.0)	128 (32.7)	144 (36.7)	22 (5.6)	**<0.001**[b]
Trust	1729 (81.5)	752 (43.5)	429 (24.8)	506 (29.3)	42 (2.4)	
Heard of vaccine incidents						
Yes	1883 (88.7)	731 (38.8)	523 (27.8)	576 (30.6)	53 (2.8)	**<0.001**[b]
No	241 (11.4)	119 (49.4)	34 (14.1)	77 (32.0)	11 (4.6)	

[a] P-value from Fisher's exact tests. [b] P-value from Chi-square tests. [c] P-value from ANOVA.
Boldface indicates statistical significance ($p<0.05$).

Table 4. Determinants of vaccine hesitancy by multinomial logistic regression (no vaccine hesitancy as reference).

Variables (reference)	Acceptors with doubts	Delayers	Refusers
Rural (urban)	0.94 (0.74 - 1.19)	0.85 (0.68 - 1.06)	1.58 (0.93 - 2.68)
Caregiver relationship with children (mother)			
Father	1.34* (1.01 - 1.76)	0.74* (0.56 - 0.99)	1.40 (0.75 - 2.60)
Grandparents and others	0.74 (0.42 - 1.30)	0.64 (0.37 - 1.12)	0.53 (0.14 - 2.08)
Age group (<=30, years)			
~35	1.48** (1.14 - 1.91)	1.37* (1.08 - 1.76)	0.77 (0.42 - 1.42)
~40	0.98 (0.67 - 1.42)	0.99 (0.70 - 1.40)	0.71 (0.29 - 1.73)
>40	0.84 (0.50 - 1.39)	0.50* (0.29 - 0.86)	0.79 (0.25 - 2.53)
Having religious beliefs	1.78** (1.16 - 2.73)	1.50 (0.99 - 2.26)	2.52* (1.11 - 5.72)
Education (middle school or below)			
High school	1.63* (1.08 - 2.47)	0.88 (0.63 - 1.22)	0.56 (0.20 - 1.56)
Junior college	2.77** (1.87 - 4.12)	1.02 (0.73 - 1.42)	1.75 (0.77 - 3.98)
Bachelor degree or above	2.62** (1.76 - 3.90)	0.85 (0.61 - 1.18)	2.35* (1.03 - 5.35)
Annual household income, 1000 Renminbi (<20)			
20-50	0.93 (0.62 - 1.39)	0.98 (0.68 - 1.42)	0.83 (0.37 - 1.85)
50-100	1.11 (0.76 - 1.62)	1.18 (0.84 - 1.67)	0.69 (0.32 - 1.50)
100-200	0.93 (0.62 - 1.38)	0.87 (0.60 - 1.26)	0.33* (0.13 - 0.84)
>200	0.99 (0.63 - 1.55)	1.21 (0.79 - 1.85)	0.40 (0.15 - 1.10)
Trust in vaccine importance	1.57 (0.79 - 3.12)	1.42 (0.74 - 2.73)	1.09 (0.34 - 3.49)
Trust in vaccine safety	0.64* (0.44 - 0.94)	0.82 (0.56 - 1.19)	0.52 (0.23 - 1.18)
Trust in vaccine effectiveness	1.27 (0.81 - 2.01)	1.01 (0.65 - 1.55)	1.03 (0.41 - 2.58)
Score of trust in system that delivers vaccines	0.83** (0.77 - 0.90)	0.86** (0.80 - 0.93)	0.86 (0.72 - 1.01)
Trust in government	0.73 (0.52 - 1.04)	0.74 (0.53 - 1.03)	0.44* (0.22 - 0.89)
Heard of vaccine incidents	1.61* (1.05 - 2.45)	1.05 (0.75 - 1.47)	0.65 (0.31 - 1.37)
Observations	2,113	2,113	2,113

Notes: Adjusted OR and 95% CI were presented. Significant level: ** p<0.01, * p<0.05.

Table 5. Proportion of participants who answered yes to each reason among those hesitant to vaccination (%)

Had you worried about, delayed or refused to vaccinate due to the following reasons?		Total sample (n=1271)	Acceptors with doubts (n=554)	Delayers (n=653)	Refusers (n=64)	p-value[a]
Complacency	I don't think I or my child will be infected with vaccine-preventable diseases.	20.5	20.4	20.4	23.4	0.840
Confidence	I think the vaccine is not effective.	9.7	11.4	7.5	17.0	**0.009**
	I think the vaccine is not safe or concern about side effects.	24.6	27.6	21.3	32.8	**0.012**
	Religious reasons	2.0	3.3	0.6	4.7	**0.001**
	Reasons from other beliefs or traditional medicine	6.6	7.1	5.1	18.8	**0.001**
Convenience	I don't have time to take my child to vaccinate.	12.3	9.0	14.4	18.8	**0.005**
	The distance to vaccination clinic is far.	8.3	7.9	7.4	20.3	**0.001**
	The vaccine price is high.	19.6	23.3	16.1	23.4	**0.005**
	Poor quality of health care system.	8.7	10.5	6.4	15.5	**0.006**
Information or experience	I heard or read negative information about vaccines through media.	62.2	65.3	60.7	53.1	0.068
	I (or someone I know) had a bad experience or reaction with previous vaccination.	25.3	25.2	23.4	40.6	**0.010**
Fear of needles	My child fears of needles.	20.6	22.4	18.4	28.1	0.072

[a] P value from Chi-square or Fishers exact tests. Boldface indicates statistical significance (p<0.05).