Assessing Vaccine Literacy and Exploring its Association with Vaccine Hesitancy: A Validation of the Vaccine Literacy Scale in China

Liuqing Yang[1,2*]; Shiqi Zhen[3*]; Lan Li[4]; Qiang Wang[1,2]; Guoping Yang[3]; Tingting Cui[1,2]; Naiyang Shi[1,2]; Shixin Xiu[5]; Lin Zhu[3]; Xuepeng Xu[3]; Liping Wang[6]; Hui Jin[1,2#]; Lili Ji[3#]

[1]Department of Epidemiology and Health Statistics, School of Public Health, Southeast University, Nanjing, PR China;

[2]Key Laboratory of Environmental Medicine Engineering, Ministry of Education, School of Public Health, Southeast University, Nanjing, PR China

[3]Jiangsu Provincial Center for Disease Control and Prevention, Nanjing, PR China

[4]Institute of Disaster Risk Reduction, University College London, London, United Kingdom.

[5]Department of Immunization Planning, Wuxi Center for Disease Control and Prevention, Wuxi, PR China

[6]Yancheng Center for Disease Control and Prevention, Yancheng, PR China

*Contributed equally

#Contributed equally as joint senior authors

Correspondence to Dr. Hui Jin, Department of Epidemiology and Health Statistics, School of Public Health, Southeast University, Nanjing, China. Email: jinhui_hld@163.com; Tel: +025 8327 2572; Fax: +825-83272561; 87# Dingjiaqiao 210009 Nanjing PR China.

Ethical Considerations

This study was ethically reviewed and approved by the Ethics Committee of the Wuxi Center for Disease Prevention and Control (2020No10).

Declaration of Interests

The authors have no conflict of interest.

Funding

This work was supported by the Wuxi City Technology Development Fund (N20191007); Postgraduate Research & Practice Innovation Program of Jiangsu Province (Grant Number: KYCX21_0160); Public Health Research Center of Jiangnan University (JUPH201845).

Author contributions

HJ, LQY, and SQZ designed the study. QW, LL, LQY, GPY, and TTC conducted the literature review and designed the questionnaire. GPY, LLJ, LZ, XPX, LPW, and NYS assisted with the online investigation. LQY, QW, and SXX analyzed the data. HJ, QW, GPY, and XPX interpreted the results. All authors critically revised the manuscript for important intellectual content. And that all authors agree to be accountable for all aspects of the work and approve the version for publication.

Abbreviations

HLVa-IT: Vaccine Health Literacy of Adults in Italian
aOR: adjusted odds ratio
CI: confidence interval
3C: confidence, convenience, and complacency
KMO: Kaiser–Meyer–Olkin
EFA: exploratory factor analysis
CFA: the confirmatory factor analysis
AVE: average variances extracted
CR: composite reliability
GFI: the goodness-of-fit index
AGFI: adjusted goodness-of-fit index
CFI: comparative fit index
RMSEA: the root means square error of approximation
IQR: interquartile range

Abstract

Background: Assessment of vaccine literacy is essential for understanding people's ability to access various vaccine information to meet health demands. Few studies have examined the role of vaccine literacy in vaccine hesitancy, which is a psychological state. This study aimed to validate the applicability of the HLVa-IT (Vaccine Health Literacy of Adults in Italian) scale in Chinese settings and to explore the association between vaccine literacy and vaccine hesitancy.

Methods: From May to June 2022, we conducted an online cross-sectional survey in mainland China. Potential factor domains were obtained by the exploratory factor analysis. Cronbach's alpha coefficient, composite reliability values, and square root values of average variances extracted were calculated to determine the internal consistency and discriminant validity. The association between vaccine literacy, vaccine acceptance, with vaccine hesitancy was assessed using logistic regression analysis.

Results: Totally, 12,586 participants completed the survey. Two potential dimensions, the functional and the interactive/critical, were identified. Cronbach's alpha coefficient and composite reliability values were greater than 0.90. The square root values of average variances extracted exceeded the related correlations. The functional dimension (adjusted odds ratio (aOR): 0579; 95% Confidence Interval (CI); 0.529, 0.635), interactive (aOR: 0.654; 95%CI: 0.531, 0.806)/critical (aOR: 0.709; 95%CI: 0.575, 0.873) dimension were significantly and negatively associated with vaccine hesitancy. Similar results were also found in different vaccines acceptance subgroups.

Limitations: This report is limited by the convenience sampling method.

Conclusions: The modified HLVa-IT is suitable for use in Chinese settings. Vaccine literacy was negatively associated with vaccine hesitancy.

Keywords: vaccine literacy, vaccine hesitancy, scale, validation

Introduction

Vaccination is one of the most effective ways to prevent outbreaks of vaccine-preventable diseases and reduce the disease burden, severe illness, and death. However, the anti-vaccine movement has grown tremendously in the past twenty years (Ratzan, 2011; Johnson et al., 2020). The increasing reliance on the Internet and social media for seeking health information has played a pivotal role in disseminating misinformation and exacerbating vaccine confidence (Johnson et al., 2020). Vaccine hesitancy was considered one of the ten issues threatening global health in 2019 (World Health Organization, 2019). Weak health literacy was identified as an important cause of low vaccine uptake (Biasio, 2019). Vaccine literacy is built on the overall idea of health literacy (Biasio et al., 2020a; Badua et al., 2022) and has been defined as "the ability to understand health information and services in order to make appropriate health-related decisions" by Biasiao (2019).

A growing body of work has linked low literacy with negative health outcomes (Kim et al., 2023), including higher health services utilization (Zulman et al., 2020), worse chronic disease prevention practice (Fawns-Ritchie et al., 2022), and mental illness (Guo et al., 2023). In many cross-sectional survey findings, subjects with low literacy were more likely to have depression (Vu et al., 2023; Alothman and Fogarty., 2020). Lincoln et al. supported the longitudinal relationship between literacy skills and depressive symptoms (Lincoln et al., 2006). Previous studies have shown that, contrary to common sense, highly educated individuals appear instead to exhibit lower vaccine acceptance (Aharon et al., 2017; Biasio et al., 2018). This suggests that high literacy levels do not exactly equate to a high reservoir of vaccine information, nor does it match with the ability to critically accept vaccine information. Therefore, the creation of a standardized scale to measure vaccine literacy is necessary. The HLVa-IT (Vaccine Health Literacy of Adults in Italian) is a scale developed in Italy (Biasio et al., 2020b), which is built on the Ishikawa test for chronic non-communicable diseases (Ishikawa et al., 2008), specifically to measure vaccine literacy and has been validated in various settings, including Croatian (Gusar et al., 2021), and Saudi Arabia (Alshehry et al., 2022). However, the applicability and validity of this scale in the Chinese setting which country has a large population have not been demonstrated.

Vaccine hesitancy is defined as a state of indecisiveness regarding a vaccination decision (Larson., 2022). In the context of decision-making, the distinction between the affective nature of vaccine hesitancy and being a behavior is crucial. The concrete example of French health pass also supported this its difference with behavior (Ward et al., 2022). Therefore, vaccine hesitancy is characterized by the changing nature of mental status, particularly the volatile and emotional. Further, the associations between vaccine hesitancy and health literacy on vaccine have not been confirmed, and it is unclear whether the association is positive or negative or whether no such association exists (Biasio, 2019; Magon et al., 2021; Willis et al., 2021).

The aim of this study was to validate the applicability of the HLVa-IT scale within

the Chinese setting and to explore the association between vaccine literacy and vaccine hesitancy.

Methods

Participants and Procedure

From May 19, 2022, to June 24, 2022, we conducted a survey in mainland China using a web-based online questionnaire. Convenience sampling was performed in this survey. The link to the questionnaire was created by "Wen Juan Xing", a professional platform for creating and disseminating questionnaires, and forwarded by the WeChat platform of the Jiangsu Provincial Center for Disease Control and Prevention. Prior to the participation, a written informed statement was provided, in which we assured participants that the study was conducted on a voluntary basis and for research purposes only. Further, completing times less than 100 seconds were automatically set invalid. Questionnaires answered by people under 18 years and over 60 years were not analyzed.

HLVa-IT was forward translated by two bilingual translators and two specific study staff. The backward translation was performed by a native English language speaker. Five translators confirmed that the final Chinese version of the questionnaire is linguistically and conceptually consistent with the original. Further, we invited three vaccine experts to recheck the applicability of the Chinese version questionnaire who were familiar with the policy of the Chinese immunization program, and they suggested changes to some items (focus on tetanus, pneumococcal, and influenza vaccine) in the "vaccine quiz" and "vaccine acceptance". To test the clarity and comprehensibility of each item, a pilot study using the modified Chinese version of the HLVa-IT questionnaire was distributed to 50 participants over 18 years. Moreover, one-to-one interviews after completion reported no poorly clarified items.

Measures

The questionnaire collected the socio-demographic variables, including age, sex, ethnicity, marital status, educational status, occupation, annual household income, residential status, number of daily contacts, chronic disease history, and self-assessment of health status.

The scale was presented in Appendix 1. The vaccine literacy was measured using the modified China-HLVa-IT questionnaire. As the same as the original HLVa-IT questionnaire, the main body of the China-HLVa-IT is composed of 14 items divided into three scales: functional (items number 1-5), interactive (items number 6-10), and critical vaccine literacy (items number 11-14). Before completing the functional scale and interactive and critical scale, the filter questions included in the original questionnaire were also set. Each item was assessed using a 5-point Likert scale, ranging from 1 to 5 (functional scale: 5-never, 4-rarely, 3-general, 2-sometimes 1-often; interactive/critical scale: 1-never, 2-rarely, 3-general, 4-sometimes 5-often).

According to the recommendation of vaccine experts, the "vaccine quiz" which is an 11 statements test (true/false/do not know) included in the original

questionnaire was modified. The item “To protect against tetanus, vaccination is offered to adults free of charge every ten years” was deleted. This is because, in China, the tetanus vaccine is inoculated for children as one of the expanded immunization program vaccines, and adults are only used for post-exposure prophylaxis (such as deep wounds) (Chinese Center for Disease Control and Prevention, 2022). In addition, the item “Influenza and pneumococcal vaccines are recommended and free of charge from age 65” was changed to “Influenza and pneumococcal vaccines are recommended for people over 65 years of age” because influenza (Yang et al., 2016)**Error! Reference source not found.** and pneumonia (Yu et al., 2012) vaccines are self-funded in most provinces of China. The other items in the original vaccine quiz were reserved and measured in true/false/do not know.

According to the modification in the vaccine quiz, the item “Have you been vaccinated against tetanus” in “vaccine acceptance” was also deleted. Two other items related to influenza and pneumonia vaccination acceptance were retained. Further, the vaccine acceptance of other vaccines, including covid-19 vaccine, covid-19 booster vaccine, hepatitis B vaccine, and herpes zoster vaccine, were also recorded.

The vaccine hesitancy dimension was measured by the item: “What is your level of hesitation about vaccinating (1-very hesitant, 2-hesitant, 3-not sure, 4-no hesitant, 5-not at all)”.

Data Analysis

Descriptive statistics were used to analyze the socio-demographic variables and China-HLVa-IT responses before conducting a factorial analysis. Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity coefficient were conducted to check the feasibility of performing factor analysis (Sievers, 2014). Half of the sample was randomly selected each for the exploratory factor analysis (EFA) and the confirmatory factor analysis (CFA). Further, the sample needed to meet the condition of selecting "yes" to the filtered items in the questionnaire before it could be included in the CFA. In EFA, factors with eigenvalues more than 1.0 were extracted using principal component analysis. And then, CFA was used to confirm the reliability (internal consistency for the items in the same latent variable) and validity (distinguishability of different latent variables) of each latent structure (factor). This study examined the parameter estimates and their associated t-values, as well as the factor loadings and the average variances extracted (AVE). Reliability was assessed by calculating the composite reliability (CR), and Cronbach’s alpha value. The square root of AVE for each latent variable was calculated to check the validity. The value of Cronbach's alpha greater than 0.7 (Streiner and Norman, 2001), CR greater than 0.6 (Fornell and Larcker, 1981), and AVE greater than 0.5 (Anderson and Gerbing, 1988) were considered acceptable. According to Gerbing et al., the goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), comparative fit index (CFI), and the root means square error of approximation (RMSEA) were used to evaluate the model fit in the CFA (Gerbing and Anderson, 2016). GFI, CFI, and AGFI are considered to be greater than 0.90

indicates a good fit; RMSEA less than 0.08 indicates a good fit (Gerbing and Anderson, 2016; Hu and Bentler, 1999).

In the vaccine quiz, incorrect answers or choosing "do not know" were scored as 0, and correct answers were scored as 1. The total score of the 11 items is the sum of the vaccine quiz scores. Spearman's correlation coefficients were calculated between vaccine quiz scores and three vaccine literacy scales, as well as the vaccine acceptance and vaccine hesitancy. We used multiple logistic regression to explore the association between vaccine literacy and vaccine hesitancy. The association between vaccine hesitancy and vaccine literacy was also examined for each vaccine acceptance condition. According to previous studies (Yang et al., 2022; Wang et al., 2021; Han et al., 2021), we used age, sex, marital status, educational status, healthcare occupation, annual household income, chronic disease history, and self-assessment of health status as control variables. "very hesitant", "hesitant", and "not sure" were combined into "hesitancy"; "no hesitant" and "not at all" were combined into "non-hesitancy". Statistical significance was defined as a two-sided P value of <0.05. All analyses were performed using SPSS 23.0 (IBM Corp, New York, NY, USA) and AMOS 23.0 (IBM Corp, New York, NY, USA) software. The Wuxi Center for Disease Control and Prevention Ethics Committee approved this study (2020No10).

Results

Participant characteristic

A total of 12,586 participants, aged over 18 years, were included in this study (Table 1). Of these, 56.1% (7,066/12,586) were male. Most participants had a college or equivalent degree (8,694/12,586, 69.1%) and did not have a healthcare-related occupation (8,140/12,586, 64.7%). Further, the proportion of households' annual income lower than USD 15,000, and the range of USD 15,000-30,000 was the highest, at 37.0% (4,656/12,586) and 48.9% (6,156/12,586), respectively. In this study, the proportion of individuals showing vaccine hesitancy was estimated to be about 34.2% (4,310/12,586).

Table 1. Participants' Sociodemographic Information

Socio-demographic	Data, n (%)
Number of participants	12586
Age (mean ± SD)	31.56±9.12
Age group	
18~24	3184 (25.3)
25~34	5362 (42.6)
35~44	2804 (22.3)
45~54	1019 (8.1)
55~64	178 (1.4)
≥65	39 (0.3)
Sex	
Male	7066 (56.1)

Female	5520 (43.9)
Marital status	
Married	8045 (63.9)
Unmarried	4300 (34.2)
Divorced	223 (1.8)
Widowed	18 (0.1)
Educational status	
Secondary school or below	766 (6.1)
High school	2087 (16.6)
College or equivalent	8694 (69.1)
Master's Diploma or above	1039 (8.3)
Healthcare occupation	
Yes	4446 (35.3)
No	8140 (64.7)
Occupation	
Government agencies and institutions	2930 (23.3)
Enterprises, commerce, service industry	5214 (41.4)
Agriculture, forestry, animal husbandry, fishery, and water conservancy production personnel	1673 (13.3)
Military	125 (1.0)
Full-time student	1097 (8.7)
Retirement	175 (1.4)
None	434 (3.4)
Others	938 (7.5)
Annual household income (USD 1,000)	
<7.5	1242 (9.9)
7.5-15	3414 (27.1)
15-22.5	3721 (29.6)
22.5-30	2435 (19.3)
30-75	1417 (11.3)
75 or more	357 (2.8)
Residential status	
Live with others	11965 (95.1)
Alone	621 (4.9)
Number of daily contacts	
1-5	2780 (22.1)
6-15	5624 (44.7)
≥16	4182 (33.2)
Chronic diseases history	
Yes	2305 (18.3)
No	10281 (81.7)
Self-assessment of health status	

Very bad	593 (4.7)
Bad	425 (3.4)
General	4178 (33.2)
Well	4318 (34.3)
Very well	3072 (24.4)
Vaccine hesitancy	
Very hesitant	773 (6.1)
Hesitant	1307 (10.4)
Not sure	2230 (17.7)
No hesitant	4504 (35.8)
Not at all	3772 (30.0)

Exploratory factor analysis of China-HLVa-IT

In this study, the value of the KMO was 0.972, and Bartlett's test of sphericity was statistically significant (p<.001), which meant that the factor analysis was applicable for this data. Approximately, 50% of the overall sample (n=6,337) was randomly selected for EFA, and the remaining sample (n=6,249) was used for CFA. In EFA, two factors were extracted that cumulatively explained 97.27% of the total variance (Supplementary Table S1). Item 6-14 were included in Factor 1 (eigenvalue=113.37), the interactive/critical dimension in HLVa-IT, with a percent variance share of 61.48%. Item 1-5, representing the functional scale, were included in Factor 2 (eigenvalue=23.272), with a percent variance share of 35.80%. All items loadings were over 0.90 (Supplementary Table S2).

Confirmatory factor analysis of China-HLVa-IT

The Cronbach's alpha values of the functional (n=5030) and interactive/critical (n=4093) scales of the China-HLVa-IT were 0.938 and 0.932, respectively. Moreover, none of the items strongly affected the reliability (over 0.90) of the dimension in tests where any item was removed in sequence (Supplementary Table S3). In addition, as shown in Supplementary Table S4 and S5, the item correlation (over 0.5) within each scale was strong.

As shown in Table 2, the factor loadings of all items in China-HLVa-IT were over 0.70. The error variances of the items were also estimated, and the specific results were presented in Supplementary Table S6. The CR values of scales were greater than 0.90, in which the functional scale was 0.941, and the interactive/critical scale was 0.931. The AVE values of these dimensions were greater than 0.60. Further, the square root of AVE of both dimensions exceeded the related correlations (Supplementary Table S7). The overall model achieved a good fit for GFI = 0.917, CFI = 0.886, AGFI = 0.954, and RMSEA = 0.079. Therefore, the reliability and validity of the China-HLVa-IT were acceptable.

Table 2. The Reliability of Items

Dimension	Parameter significance estimation				Factor loading	SMC [d]	CR [e]	AVE [f]
	Unstd.[a]	S.E. [b]	t-value	p-value	Std. [c]			

Functional								
Item 1	1.000				0.822	0.676	0.941	0.760
Item 2	1.010	0.016	63.821	<.001	0.846	0.716		
Item 3	1.079	0.015	71.405	<.001	0.908	0.824		
Item 4	1.066	0.015	70.858	<.001	0.904	0.817		
Item 5	1.081	0.016	67.533	<.001	0.877	0.769		
Interactive/Critical								
Item 6	1.000				0.748	0.560	0.931	0.602
Item 7	1.062	0.021	50.153	<.001	0.788	0.621		
Item 8	1.009	0.020	49.434	<.001	0.777	0.604		
Item 9	1.059	0.021	51.136	<.001	0.801	0.642		
Item 10	1.015	0.023	44.688	<.001	0.710	0.504		
Item 11	1.068	0.021	51.148	<.001	0.801	0.642		
Item 12	1.056	0.021	49.824	<.001	0.783	0.613		
Item 13	1.067	0.021	50.326	<.001	0.790	0.624		
Item 14	1.043	0.021	49.466	<.001	0.778	0.605		

a. Unstd. is the abbreviation of unstandardized estimate
b. S.E. is the abbreviation of standard error
c. Std. is the abbreviation of standardized estimate
d. SMC is the abbreviation of squared multiple correlations
e. CR is the abbreviation of composite reliability
f. AVE is the abbreviation of average variances extracted

Description of scale's results

Totally, 10,124 participants completed the functional scale questions, and approximately one-third to one-half of the participants have difficulties understanding the scientific information about vaccination; 8,228 participants completed the interactive/critical scale, and more than 70% of the participants actively seek information and screen it for accuracy (Figure 1). The mean value of the Likert score for each item in the functional scale was 3.23±1.24; the interactive scale was 4.03±0.81; the critical scale was 4.03±0.84. A total of 7,731 participants completed both the functional and interactive/critical dimensions, and the mean vaccine literacy value was 52.16±8.93. For the vaccine quiz, the median score was 6 [interquartile range (IQR): 4, 8], with a range from 0 to 11. In terms of vaccine acceptance, 16.3% (2,046/12,586) of participants self-reported never having received an influenza vaccine, 42.1% (5,299/12,586) received an influenza vaccine within one year, 21.2% (2,667/12,586) within two years, 8.7% (1,092/12,586) within three years, and 11.8% (1,482/12,586) reported having received an influenza vaccine more than three years ago. A total of 1599 participants reported not having received the COVID-19 vaccine, and 3016 participants had not received the booster COVID-19 vaccine. Hepatitis B vaccine and herpes zoster vaccine were given to 40.9% (5,146/12,586), and 5.6% (711/12,586) of the participants, respectively. The pneumonia vaccine was administered to 14.4% of the participants.

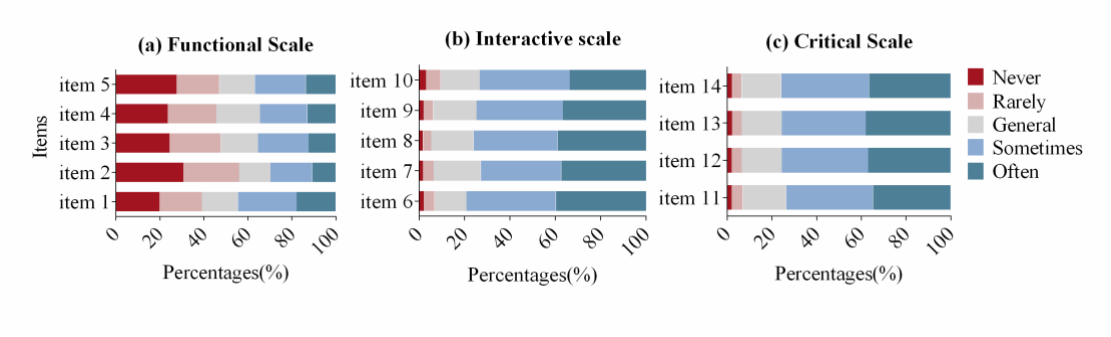

Figure 1. participants' vaccine literacy

As shown in the Supplementary Table S8 and S9, there were significant positive correlations between the three scales of vaccine literacy in China-HLVa-IT and the vaccine quiz, including the functional scale (Spearman r=0.365, p<.001), the interactive scale (Spearman r=0.157, p<.001), and the critical scale (Spearman r=0.149, p<.001). Further, the total score of three scales which represented vaccine literacy was also positive associate with vaccine quiz (Spearman r=0.416, p<.001). Additionally, the score of the vaccine quiz was positively correlated with the COVID-19 (Spearman r=0.223, p<.001), booster COVID-19 vaccine (Spearman r=0.147, p<.001), hepatitis B vaccine (Spearman r=0.192, p<.001), and herpes zoster vaccine (Spearman r=0.022, p=.012). However, the influenza vaccine (Spearman r=0.014, p=.128) and the pneumonia vaccine (Spearman r=0.009, p=.329) acceptance were not statistically correlated with the vaccine quiz score. In addition, the functional scale was negatively correlated with pneumonia vaccine (Spearman r=-0.062, p<.001) acceptance. The interactive scale (Spearman r=-0.049, p<.001) and critical scale (Spearman r=-0.035, p<.001) were negatively correlated with influenza vaccine acceptance.

Vaccine literacy and vaccine hesitancy

In the subgroup of hesitancy, the mean score of the functional, interactive, and critical scales were 2.84±1.07, 3.77±0.77, and 3.77±0.80, respectively. In the subgroup of non-hesitancy, the mean scores of the three literacy scales were 3.41±1.27 (functional), 4.15±0.80 (interactive), and 4.14±0.83 (critical), respectively. The differences in mean scores of the three scales (functional: p<.001; interactive: p<.001; critical: p<.001) between the hesitant and non-hesitant groups were statistically significant. Detailed information was presented in Figure 2.

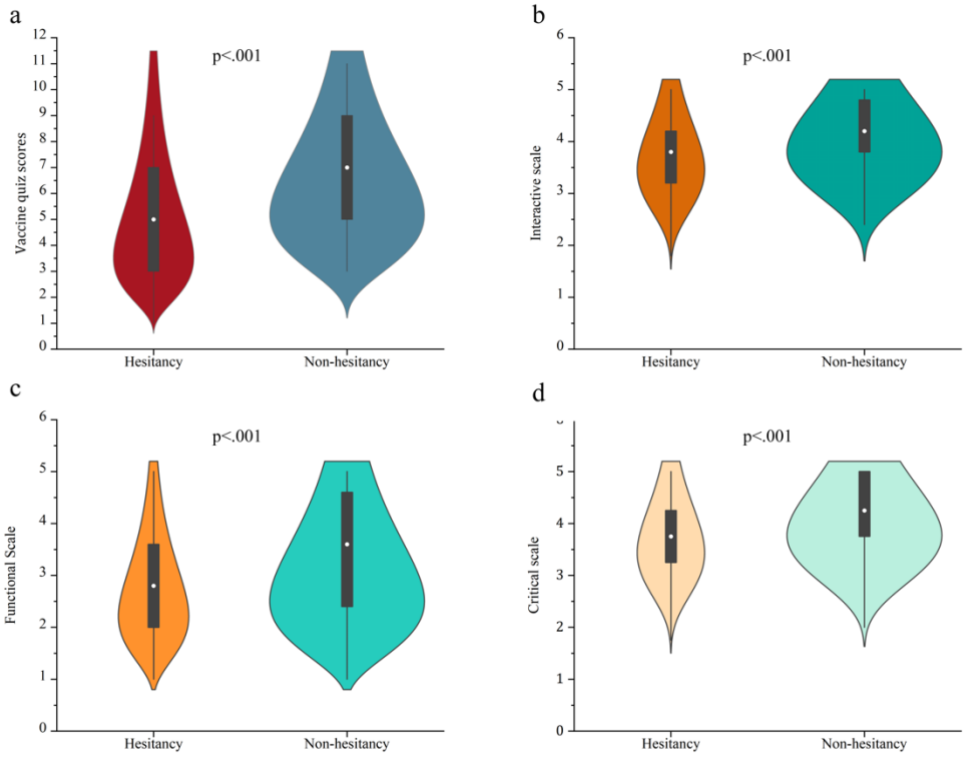

Figure 2. Scores of vaccine literacy scale among different vaccine hesitancy status

After adjusting for socio-demographics, we found statistically significant associations between different scales of vaccine literacy and vaccine hesitancy (Figure 3 and Supplementary Table S10). Compared with those in the 18-24 age group, people aged 45-64 years had less vaccine hesitation (45-54 years: adjusted odds ratio (aOR): 0.760, 95% Confidence Interval (CI): 0.631, 0.916, p=.004) (55-64 years: aOR: 0.673, 95%CI: 0.466, 0.973, p=.035). Compared with married people, those who were unmarried (aOR: 1.349, 95%CI: 1.218, 1.495, p<.001) or divorced (aOR: 1.649, 95%CI: 1.234, 2.205, p=.001) were more hesitancy. People with a high school (aOR: 0.806, 95%CI: 0.672, 0.966, p=.019) or college degree (aOR: 0.636, 95%CI: 0.539, 0.752, p<.001) were less likely to be vaccine hesitant than those with a secondary school or lower degree. People who had a higher annual household income (p<.001) were less likely to be hesitant. People who had no chronic diseases (p<.001) and self-reported had well health status (p<.001) were less likely to be hesitant. People who scored lower on the vaccine literacy scales were more likely to be vaccine hesitancy (functional: aOR: 0579, 95%CI: 0.529, 0.635, p<.001) (interactive: aOR: 0.654, 95%CI: 0.531, 0.806, p<.001) (critical: aOR: 0.709, 95%CI: 0.575, 0.873, p=.001).

In different vaccine acceptance subgroups, the findings were also similar to that of the total participants. Compared with married people, unmarried status was the risk factor in all vaccine acceptance subgroups, including influenza vaccine (aOR:

1.467, 95%CI: 1.282, 1.679, p<.001), pneumonia vaccine (aOR: 1.837, 95%CI: 1.457, 2.317, p<.001), COVID-19 vaccine (aOR: 1.276, 95%CI: 1.136, 1.433, p<.001), COVID-19 vaccine booster (aOR: 1.381, 95%CI: 1.220, 1.564, p<.001), hepatitis B vaccine (aOR: 1.578, 95%CI: 1.372, 1.815, p<.001), and herpes zoster vaccine (aOR: 2.073, 95%CI: 1.407, 3.053, p<.001). Compared with people who self-reported "very bad" health status, those who self-reported "very well" were less likely to be hesitancy in influenza vaccine (aOR: 0.292, 95%CI: 0.213, 0.402, p<.001), pneumonia vaccine (aOR: 0.330, 95%CI: 0.203, 0.535, p<.001), COVID-19 vaccine (aOR: 0.324, 95%CI: 0.258, 0.408, p<.001), COVID-19 vaccine booster (aOR: 0.372, 95%CI: 0.292, 0.474, p<.001), hepatitis B vaccine (aOR: 0.365, 95%CI: 0.256, 0.519, p<.001), and herpes zoster vaccine acceptance (aOR: 0.141, 95%CI: 0.061, 0.326, p<.001). Further, people who scored lower on the functional scale were more likely to be hesitant in all vaccine acceptance. Detailed information was presented in Supplementary Table S11, S12, S13, S14, and S15, and Figure 3.

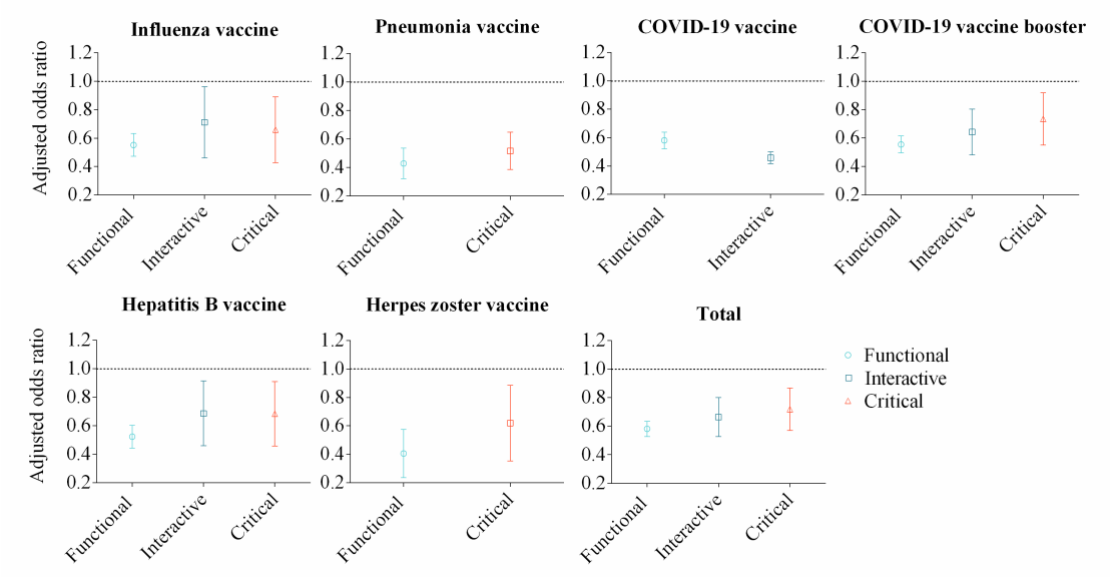

Figure 3. Association between vaccine hesitancy and vaccine literacy*

*adjusted for age, sex, marital status, educational status, healthcare occupation, annual household income, chronic disease, and self-assessment of health status. The logistic regression used the forward selection (conditional) method. Therefore, the interactive scale was removed in the pneumonia vaccine and herpes zoster vaccine subgroups, and the critical scale was removed in the COVID-19 vaccine subgroup.

Discussion

Our findings demonstrated that the vaccine literacy scale has two domains, "functional" and "interactive/critical", and its reliability, validity, and model fit are acceptable in Chinese settings. The mean score of the functional scale is lower than the interactive and critical scales. Participants with higher scores on the literacy scale are less likely to show vaccine hesitancy. The scores of the interactive and critical scales in vaccine literacy were negatively correlated with influenza vaccine

acceptance.

Consistent with previous studies (Biasio et al., 2020a; Gusar et al., 2021; Alshehry et al., 2021), two domains were identified in the questionnaire, namely “functional” and “interactive/critical”. The high scores on the interactive and critical scales represented participants’ greater willingness to use information critically. This was despite the fact that the lower scores on the functional scale which was on behalf of the low level of population’s health knowledge in mainland China, both in the vaccine hesitancy and non-hesitancy subgroups. This also confirmed what was reflected in the previous survey, that people's intention to be vaccinated was more associated with subjective norms, i.e., the opinions of doctors, relatives, and the surroundings (Yang et al., 2022).

Our findings also suggested that the acceptance of the COVID-19 vaccine and booster shots was positively associated with the level of the population's understanding and critically using the information obtained. This may be due to the great efforts taken by the Chinese government to speed up the dissemination of scientific information and vaccination. In China, the influenza vaccine is not included in the national immunization program. Over the past approximately two decades, flu vaccine coverage has only gradually increased to about 2% of the population (Yang et al., 2016; Li et al., 2019).

Additionally, our findings indicated that higher scores on interactive and critical scales were associated with lower acceptance of influenza vaccination. A large systematic review also supports our findings (Lorini et al., 2018). The low cost of influenza vaccination in China makes the less concerned about cost and more concerned about quality and safety, leading to a decrease in vaccination uptake (Lv et al., 2016). Some studies have also shown that there is a false belief that "getting a flu shot can catch the flu” (Nyhan and Reifler, 2015). Moreover, previous studies have shown that correcting misconceptions of facts may be ineffective and even make false beliefs more prevalent because people are motivated to defend their prior beliefs (Nyhan, 2021; Nyhan et al., 2011). Low levels of knowledge about vaccine health may contribute to the spread of health misinformation and are associated with lower vaccination rates (Kricorian et al., 2022). This is consistent with the results of our study that lower vaccine literacy was associated with more vaccine hesitancy.

Limitations

This study had several limitations. The convenience sampling method was taken in this study and therefore had a large proportion of respondents with high educational and medical backgrounds; however, the low-educated population may have lower vaccine literacy. Thus, the results of this study may overestimate the level of vaccine literacy in mainland China. We have adjusted participants’ demographics in the logistic regression analysis. Additionally, vaccine hesitancy was measured by one self-reported item for avoiding response fatigue.

Conclusions

In this study, the China-HLVa-IT had two dimensions and had acceptable internal

consistency and discriminant validity. China-HLVa-IT can be used in Chinese settings.

Little attention has been paid to vaccine literacy in vaccine hesitancy settings, which hesitation has emerged as a new branch of psychology in recent years. These findings indicate that vaccine literacy was an import factor in the changing course of the sentiments around the vaccines, also described as vaccine hesitancy.

Acknowledgements

We would like to thank all people who participated in this survey for their contributions to this study.

Reference

Alothman, D., Fogarty, A., 2020. Global differences in geography, religion and other societal factors are associated with sex differences in mortality from suicide: An ecological study of 182 countries. J Affect Disord. 260, 67–72. https://doi.org/10.1016/j.jad.2019.08.093

Anderson JC, Gerbing DW., 1988. Structural equation modeling in practice: a review and recommended two-step approach. Psychol Bull. 103(3):411-423. http://doi.org/10.1037/0033-2909.103.3.411.

Aharon AA, Nehama H, Rishpon S, Baron-Epelb O., 2017. Parents with high levels of communicative and critical health literacy are less likely to vaccinate their children. Patient Educ Couns. 100(4):768–75. http://doi.org/10.1016/j.pec.2016.12.022.

Alshehry AS, Cruz JP, Alquwez N, Alsharari AF, Tork HMM, Almazan JU, Alshammari F, Alabdulaziz H, Alsolami F, Tumala RB, Al Thobaity A, Alqahtani FM, Balay-Odao E., 2022. Predictors of nursing students' intention to receive COVID-19 vaccination: A multi-university study in Saudi Arabia. J Adv Nurs. 78(2):446-457. http://doi.org/10.1111/jan.15002.

Biasio LR, Carducci A, Fara GM, Giammanco G, Lopalco PL., 2018. Health literacy, emotionality, scientific evidence: elements of an effective communication in public health. Hum Vaccin Immunother. 14(6):1515–16. http://doi.org/1080/21645515.2018.1434382.

Biasio LR. Vaccine literacy is undervalued. Hum Vaccin Immunother. 2019. 15(11):2552-2553. http://doi.org/10.1080/21645515.2019.1609850.

Biasio, L.R., Bonaccorsi, G., Lorini, C. & Pecorelli, S., 2020a. Assessing COVID-19 vaccine literacy: A preliminary online survey. Human Vaccines & Immunotherapeutics, 17 (5), 1304– 1312. https://doi.org/10.1080/21645515.2020.1829315.

Biasio LR, Giambi C, Fadda G, Lorini C, Bonaccorsi G, D'Ancona F., 2020b. Validation of an Italian tool to assess vaccine literacy in adulthood vaccination: a pilot study. Ann Ig. 32(3):205-222. http://doi.org/10.7416/ai.2020.2344.

Badua AR, Caraquel KJ, Cruz M, Narvaez RA., 2022 Vaccine literacy: A concept analysis. Int J Ment Health Nurs. 31(4):857-867. http://doi.org/ 10.1111/inm.12988.

Chinese Center for Disease Control and Prevention, 2022. The tetanus in the national immunization program. https://www.chinacdc.cn/nip/kpyd/xjxcrb/psf/ (Accessed 17 July 2022).

Fawns-Ritchie C, Price J, Deary IJ., 2022. Association of functional health literacy and cognitive ability with self-reported diabetes in the English Longitudinal Study of Ageing: a prospective cohort study. BMJ open. 12(6), e058496. https://doi.org/10.1136/bmjopen-2021-058496

Fornell C, Larcker DF., 1981. Evaluating structural equation models with unobservable variables and measurement error. J Mark Res. 18(1):39. http://doi.org/10.2307/3151312.

Guo, C., Cui, Y., Xia, Z., Hu, J., Xue, Y., Huang, X., Wan, Y., Fang, J., Zhang, S., 2023. Association between health literacy, depressive symptoms, and suicide-related outcomes in adolescents: A longitudinal study. J Affect Disord. 327, 15–22. https://doi.org/10.1016/j.jad.2023.01.054

Gerbing DW, Anderson JC., 2016. Monte Carlo evaluations of goodness of fit indices for structural equation models. Sociol Methods Res. 21(2):132-160. http://doi.org/10.1177/0049124192021002002]

Gusar I, Konjevoda S, Babić G, Hnatešen D, Čebohin M, Orlandini R, Dželalija B., 2021. Pre-Vaccination COVID-19 Vaccine Literacy in a Croatian Adult Population: A Cross-Sectional Study. Int J Environ Res Public Health. 18(13):7073. http://doi.org/10.3390/ijerph18137073.

Hu L, Bentler PM., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Modeling. 6(1):1-55. http://doi.org/10.1080/10705519909540118.

Han Y, Wang Q, Zhao S, Wang J, Dong S, Cui T, Liu M, Shi N, Yang L, Han Y, Xiu S, Wang X, Jin H., 2022. Parental category B vaccine hesitancy and associated factors in China: an online cross-sectional survey. Expert Rev Vaccines. 21(1):145-153. http://doi.org/10.1080/14760584.2022.2008247.

Ishikawa H, Takeuchi T, Yano E., 2008. Measuring functional, communicative, and critical health literacy among diabetic patients. Diabetes Care. 31(5):874–79. http://doi.org/10.2337/dc07-1932.

Johnson NF, Velásquez N, Restrepo NJ, Leahy R, Gabriel N, El Oud S, Zheng M, Manrique P, Wuchty S, Lupu Y, et al., 2020. The online competition between pro- and anti-vaccination views. Nature. 582(7811):230–33. http://doi.org/10.1038/s41586-020-2281-1.

Kim, K., Shin, S., Kim, S., Lee, E., 2023. The Relation Between eHealth Literacy and Health-Related Behaviors: Systematic Review and Meta-analysis. J Med Internet Res. 25, e40778. https://doi.org/10.2196/40778

Kricorian K, Civen R, Equils O., 2022. COVID-19 vaccine hesitancy: misinformation and perceptions of vaccine safety. Hum Vaccin Immunother. 18(1):1950504. http://doi.org/10.1080/21645515.2021.1950504.

Lincoln, A., Paasche-Orlow, M. K., Cheng, D. M., Lloyd-Travaglini, C., Caruso, C., Saitz, R., Samet, J. H., 2006. Impact of health literacy on depressive symptoms and mental health-related: quality of life among adults with addiction. J Gen Intern

Med, 21(8), 818–822. https://doi.org/10.1111/j.1525-1497.2006.00533.x
Larson H. J., 2022. Defining and measuring vaccine hesitancy. Nat Hum Behav. 6(12), 1609–1610. https://doi.org/10.1038/s41562-022-01484-7
Lv M, Fang R, Wu J, Pang X, Deng Y, Lei T, Xie Z., 2016. The free vaccination policy of influenza in Beijing, China: The vaccine coverage and its associated factors. Vaccine. 34(18):2135-40. http://doi.org/10.1016/j.vaccine.2016.02.032.
Lorini C, Santomauro F, Donzellini M, Capecchi L, Bechini A, Boccalini S, Bonanni P, Bonaccorsi G., 2018. Health literacy and vaccination: A systematic review. Hum Vaccin Immunother. 14(2):478-488. http://doi.org/ 10.1080/21645515.2017.1392423.
Li L, Liu Y, Wu P, Peng Z, Wang X, Chen T, Wong JYT, Yang J, Bond HS, Wang L, Lau YC, Zheng J, Feng S, Qin Y, Fang VJ, Jiang H, Lau EHY, Liu S, Qi J, Zhang J, Yang J, He Y, Zhou M, Cowling BJ, Feng L, Yu H., 2019. Influenza-associated excess respiratory mortality in China, 2010-15: a population-based study. Lancet Public Health. 4(9):e473-e481. http://doi.org/10.1016/S2468-2667(19)30163-X.
MacDonald NE; SAGE Working Group on Vaccine Hesitancy., 2015. Vaccine hesitancy: Definition, scope and determinants. Vaccine. 33(34):4161-4. http://doi.org/10.1016/j.vaccine.2015.04.036.
Magon A, Arrigoni C, Graffigna G, Barello S, Moia M, Palareti G, Caruso R., 2021. The effect of health literacy on vaccine hesitancy among Italian anticoagulated population during COVID-19 pandemic: the moderating role of health engagement. Hum Vaccin Immunother. 17(12):5007-5012. http://doi.org/10.1080/21645515.2021.1984123.
Nyhan B, Reifler J., 2015. Does correcting myths about the flu vaccine work? An experimental evaluation of the effects of corrective information. Vaccine. 33(3):459-64. http://doi.org/10.1016/j.vaccine.2014.11.017.
Nyhan B., 2021. Why the backfire effect does not explain the durability of political misperceptions. Proc Natl Acad Sci U S A. 118(15):e1912440117. http://doi.org/10.1073/pnas.1912440117.
Nyhan B, Porter E, Wood TJ., 2022. Time and skeptical opinion content erode the effects of science coverage on climate beliefs and attitudes. Proc Natl Acad Sci U S A. 119(26):e2122069119. http://doi.org/10.1073/pnas.2122069119.
Ratzan SC., 2011. Vaccine literacy: A new shot for advancing health. J Health Commun. 16:227–9. http://doi.org/10.1080/10810730.2011.561726.
Streiner, D.L., Norman, G.R., 2001. Health Measurement scales: A practical guide to their development and use. New York, NY: Oxford University Press.
Sievers, C., Akmatov, M.K., Kreienbrock, L., Hille, K., Ahrens, W., Gunther, K., Krause, G., 2014. Evaluation of a questionnaire to assess selected infectious diseases and their risk factors. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz, 57(11), 12831291. http://doi.org/10.1007/ s00103-014-2052-y.
Vu, T. T., Lu, W., Weiss, M., Thi-Hoai Nguyen, L., Ngo, V. K., 2023. Mental Health, Functional Impairment, and Barriers to Mental Health Access Among Cancer

Patients in Vietnam. Psycho-oncology. Advance online publication. https://doi.org/10.1002/pon.6114

World Health Organization, 2019. Ten threats to global health in 2019. https://www.who.int/newsroom/features tories/ten-threats-toglobal-health-in-2019. (accessed 18 June 2021).

Ward, J. K., Gauna, F., Gagneux-Brunon, A., Botelho-Nevers, E., Cracowski, J. L., Khouri, C., Launay, O., Verger, P., Peretti-Watel, P., 2022. The French health pass holds lessons for mandatory COVID-19 vaccination. Nature medicine. 28(2), 232–235. https://doi.org/10.1038/s41591-021-01661-7

Willis DE, Andersen JA, Bryant-Moore K, Selig JP, Long CR, Felix HC, Curran GM, McElfish PA., 2021. COVID-19 vaccine hesitancy: Race/ethnicity, trust, and fear. Clin Transl Sci. 14(6):2200-2207. http://doi.org/10.1111/cts.13077.

Wang Q, Yang L, Jin H, Lin L., 2021. Vaccination against COVID-19: A systematic review and meta-analysis of acceptability and its predictors. Prev Med. 150:106694. http://doi.org/10.1016/j.ypmed.2021.106694.

Yu H, Yang W, Varma JK., 2012. To save children's lives, China should adopt an initiative to speed introduction of pneumonia vaccines. Health Aff (Millwood). 31(11):2545-53. http://doi.org/10.1377/hlthaff.2011.1272.

Yang J, Atkins KE, Feng L, Pang M, Zheng Y, Liu X, Cowling BJ, Yu H., 2016. Seasonal influenza vaccination in China: Landscape of diverse regional reimbursement policy, and budget impact analysis. Vaccine. 34(47):5724-5735. http://doi.org/10.1016/j.vaccine.2016.10.013.

Yang L, Ji L, Wang Q, Xu Y, Yang G, Cui T, Shi N, Zhu L, Xiu S, Jin H, Zhen S., 2022. Vaccination Intention and Behavior of the General Public in China: Cross-sectional Survey and Moderated Mediation Model Analysis. JMIR Public Health Surveill. 8(6):e34666. http://doi.org/10.2196/34666.

Zulman, D. M., Maciejewski, M. L., Grubber, J. M., Weidenbacher, H. J., Blalock, D. V., Zullig, L. L., Greene, L., Whitson, H. E., Hastings, S. N., Smith, V. A., 2020. Patient-Reported Social and Behavioral Determinants of Health and Estimated Risk of Hospitalization in High-Risk Veterans Affairs Patients. JAMA Netw Open. 3(10):e2021457. http://doi.org/10.1001/jamanetworkopen.2020.21457.

Appendix 1

Supplementary Material 1. The modified vaccine literacy scale

Supplementary Material 1. The modified vaccine literacy scale

Vaccine literacy

"Have you ever read vaccine materials, such as leaflets or posters in doctor's or public health units' offices, recommending vaccinations?" □No □Yes – If yes, fill in the box below, marking with an "✓" the boxes corresponding to your choice (choose only one answer for each question)						
Reading the material:		Never	Rarely	General	Sometimes	Often
Score=		5	4	3	2	1
1	Did you find that the material as a whole (texts and/or images) was difficult to read?	□	□	□	□	□
2	Did you find words you did not know?	□	□	□	□	□
3	Did you find that the texts were difficult to understand?	□	□	□	□	□
4	Did you need much time to understand them?	□	□	□	□	□
5	Did you or would you have needed someone to help you understand them?	□	□	□	□	□
"Have you ever thought or been advised to vaccinate yourself against one or more diseases?" □No □Yes – If yes, fill in the box below, marking with an "✓" the boxes corresponding to your choice (choose only one answer for each question)						
Reading the material:		Never	Rarely	General	Sometimes	Often
Score=		1	2	3	4	5
6	Have you consulted more than one source of information?	□	□	□	□	□
7	Did you find the information you were looking for?	□	□	□	□	□
8	Did you understand the information found?	□	□	□	□	□
9	Have you had the opportunity to use the information?	□	□	□	□	□
10	Did you discuss what you understood about vaccinations with your doctor or other people?	□	□	□	□	□
11	Did you consider whether the information collected was about your condition?	□	□	□	□	□
12	Have you considered the credibility of the sources?	□	□	□	□	□
13	Did you check whether the information was correct?	□	□	□	□	□
14	Did you find any useful information to make a decision on whether or not to get vaccinated?	□	□	□	□	□

Vaccine quiz

1	It is possible to start vaccinating at any age.	□ True	□ False	□ Do not know
2	There is no vaccine for shingles.	□ True	□ False	□ Do not know
3	Vaccines can cause autism, encephalitis, asthma or epilepsy.	□ True	□ False	□ Do not know
4	Too many vaccines weaken the immune system.	□ True	□ False	□ Do not know
5	Vaccine-preventable diseases are not serious, cannot require hospitalization or be fatal.	□ True	□ False	□ Do not know

6	Vaccines are not only for children. They can also help adults to maintain good health.	□ True	□ False	□ Do not know
7	The pneumococcal vaccine protects against certain types of pneumonia.	□ True	□ False	□ Do not know
8	Influenza and pneumococcal vaccines are recommended for people over 65 years of age.	□ True	□ False	□ Do not know
9	No one has been dying of measles for decades.	□ True	□ False	□ Do not know
10	Pregnant women cannot be vaccinated.	□ True	□ False	□ Do not know
11	Vaccination is an important prevention option for patients with chronic diseases	□ True	□ False	□ Do not know

Vaccine acceptance

1	Have you ever been vaccinated against influenza?	□ Yes	□ No
2	Have you ever been vaccinated against pneumococcus?	□ Yes	□ No
3	Have you ever been vaccinated against covid-19?	□ Yes	□ No
4	Have you ever gotten the booster covid-19 vaccine?	□ Yes	□ No
5	Have you ever been vaccinated against hepatitis B?	□ Yes	□ No
6	Have you ever been vaccinated against herpes zoster?	□ Yes	□ No

Appendix 2

Supplementary Table S1. Total variance explained by the two factors in EFA
Supplementary Table S2. Factor matrix in EFA
Supplementary Table S3. Cronbach's alpha values of the China-HLVa-IT
Supplementary Table S4. Item correlation in functional scale
Supplementary Table S5. Item correlation in interactive/critical scale
Supplementary Table S6. The Estimate of Variances
Supplementary Table S7. The Validity of the Constructs
Supplementary Table S8. The correlation between vaccine literacy and vaccine quiz
Supplementary Table S9. The correlation between vaccine literacy and vaccine quiz with vaccine acceptance
Supplementary Table S10. The association between vaccine hesitancy and vaccine literacy

Supplementary Table S1. Total variance explained by the two factors in EFA

Factor	Initial Eigenvalue			Extracting on Sums of Squared Loading			Rotation Sums of Squared Loadings		
	total	percentage of variance (%)	Cumulative (%)	total	percentage of variance (%)	Cumulative (%)	total	percentage of variance (%)	Cumulative (%)
1	10.46	74.70	74.70	10.46	74.70	74.70	8.61	61.48	61.48
2	3.16	22.57	97.27	3.16	22.57	97.27	5.01	35.80	97.27

Supplementary Table S2. Factor matrix in EFA

Items	Item loading			
	Factor matrix		Rotation factor matrix [a]	
	Factor 1	Factor 2	Factor 1	Factor 2
Item 1	0.672	0.699	0.229	0.942
Item 2	0.679	0.698	0.235	0.945
Item 3	0.678	0.712	0.228	0.957
Item 4	0.685	0.703	0.238	0.952
Item 5	0.688	0.695	0.245	0.947
Item 6	0.952	-0.273	0.960	0.244
Item 7	0.951	-0.283	0.964	0.234
Item 8	0.951	-0.284	0.964	0.234
Item 9	0.953	-0.276	0.962	0.242
Item 10	0.950	-0.269	0.956	0.246
Item 11	0.952	-0.280	0.963	0.237
Item 12	0.950	-0.283	0.963	0.234
Item 13	0.951	-0.281	0.963	0.236
Item 14	0.951	-0.281	0.963	0.236

a. Varimax rotation with Kaiser normalization.

Supplementary Table S3. Cronbach's alpha values of the China-HLVa-IT

Scales	Items	Cronbach's alpha after removing this item
Functional	Item 1	0.932
	Item 2	0.927
	Item 3	0.916
	Item 4	0.918
	Item 5	0.922
Interactive	Item 6	0.926
	Item 7	0.924
	Item 8	0.924
	Item 9	0.923
	Item 10	0.928
Critical	Item 11	0.923
	Item 12	0.924
	Item 13	0.923
	Item 14	0.924

Supplementary Table S4. Item correlation in functional scale

Items	Item 1	Item 2	Item 3	Item 4	Item 5
Item 1	1.000	0.691	0.744	0.720	0.701
Item 2	0.691	1.000	0.771	0.751	0.729
Item 3	0.744	0.771	1.000	0.811	0.787
Item 4	0.720	0.751	0.811	1.000	0.804
Item 5	0.701	0.729	0.787	0.804	1.000

Supplementary Table S5. Item correlation in interactive/critical scale

Items	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13	Item 14
Item 6	1.000	0.647	0.642	0.636	0.539	0.571	0.564	0.549	0.555
Item 7	0.647	1.000	0.705	0.704	0.521	0.612	0.563	0.579	0.565
Item 8	0.642	0.705	1.000	0.709	0.507	0.587	0.577	0.564	0.561
Item 9	0.636	0.704	0.709	1.000	0.554	0.622	0.579	0.592	0.588
Item 10	0.539	0.521	0.507	0.554	1.000	0.634	0.573	0.568	0.584
Item 11	0.571	0.612	0.587	0.622	0.634	1.000	0.649	0.663	0.640
Item 12	0.564	0.563	0.577	0.579	0.573	0.649	1.000	0.702	0.683

Supplementary Table S6. The Estimate of Variances

Dimensions	Items	Variances			
		Estimate	SE	t-value	p-value
Functional	Item 1	1.361	0.044	30.806	<.001
	Item 2	0.651	0.017	38.398	<.001
	Item 3	0.550	0.015	37.235	<.001
	Item 4	0.337	0.011	31.333	<.001
	Item 5	0.346	0.011	31.983	<.001
Interactive/Critical	Item 6	0.494	0.019	26.637	<.001
	Item 7	0.390	0.010	39.807	<.001
	Item 8	0.341	0.009	38.631	<.001
	Item 9	0.329	0.008	38.969	<.001
	Item 10	0.309	0.008	38.116	<.001
	Item 11	0.501	0.012	40.614	<.001
	Item 12	0.314	0.008	38.109	<.001
	Item 13	0.348	0.009	38.790	<.001
	Item 14	0.350	0.009	38.546	<.001

a. S.E. is the abbreviation of standard error

Supplementary Table S7. The Validity of the Constructs

Dimensions	AVE [a]	Functional	Interactive/Critical
Functional	0.760	0.872	
Interactive/Critical	0.602	0.096	0.776

a. AVE is the abbreviation of average variances extracted

Supplementary Table S8. The correlation between vaccine literacy and vaccine quiz

Vaccine literacy	Spearman rho	
	Vaccine quiz	p-value
Functional scale(n=10124)	0.365	P<.001
Interactive scale(n=8228)	0.157	P<.001
Critical scale(n=8228)	0.149	P<.001
All scales	0.416	P<.001

Supplementary Table S9. The correlation between vaccine literacy and vaccine quiz with vaccine acceptance

Vaccine acceptance	Spearman rho							
			Vaccine literacy					
	Vaccine quiz (n=12586)	p-value	Functional scale (n=10124)	p-value	Interactive scale (n=8228)	p-value	Critical scale (n=8228)	p-value
Influenza vaccine	0.014	P=.128	0.060	P<.001	-0.049	P<.001	-0.035	P<.001
COVID-19 vaccine	0.223	P<.001	0.231	P<.001	0.034	P=.002	0.059	P<.001
Booster COVID-19 vaccine	0.147	P<.001	0.088	P<.001	0.074	P<.001	0.070	P<.001
Hepatitis B	0.192	P<.001	0.144	P<.001	0.068	P<.001	0.076	P<.001
Pneumonia vaccine	0.009	P=.329	-0.062	P<.001	0.065	P<.001	0.057	P<.001
Herpes zoster vaccine	0.022	P=.012	-0.014	P=.173	0.050	P<.001	0.054	P<.001

Supplementary Table S10. The association between vaccine hesitancy and vaccine literacy in total participants

Variables	aOR [a]	95% CI [b]		p-value
		Lower	Upper	
Age group ("18-24 years" as ref)				P=.001
25-34 years	1.018	0.913	1.136	P=.747
35-44 years	1.004	0.875	1.151	P=.960
45-54 years	0.760	0.631	0.916	P=.004
55-64 years	0.673	0.466	0.973	P=.035
≥65 years	0.496	0.237	1.038	P=.063
Marital status ("married" as ref)				P<.001
Unmarried	1.349	1.218	1.495	P<.001
Divorced	1.649	1.234	2.205	P=.001
Widowed	2.416	0.877	6.651	P=.088
Educational status ("secondary school or below" as ref)				P<.001
High school	0.806	0.672	0.966	P=.019
College or equivalent	0.636	0.539	0.752	P<.001
Master's Diploma or above	0.993	0.802	1.230	P=.948
Healthcare occupation	0.822	0.752	0.899	P<.001
Annual household income (USD 1,000) ("<7.5" as ref)				P<.001
7.5-15	0.739	0.641	0.852	P<.001
15-22.5	0.794	0.687	0.918	P=.002
22.5-30	0.601	0.513	0.705	P<.001
30-75	0.532	0.443	0.639	P<.001
75 or more	0.610	0.462	0.804	P<.001
Chronic diseases history	0.478	0.428	0.533	P<.001

Self-assessment of health status ("very bad" as ref)				P<.001
bad	1.337	1.023	1.749	P=.034
general	0.867	0.718	1.047	P=.138
well	0.486	0.402	0.588	P<.001
Very well	0.330	0.272	0.401	P<.001
Functional scale	0.579	0.529	0.635	P<.001
Interactive scale	0.654	0.531	0.806	P<.001
Critical scale	0.709	0.575	0.873	P=.001

a. aOR is the abbreviation of adjusted odds ratio;

b. CI is the abbreviation of the confidence interval.

Supplementary Table S11. The association between vaccine hesitancy and vaccine literacy in influenza vaccine acceptance subgroup

Variables	aOR [a]	95% CI [b]		p-value
		Lower	Upper	
Marital status ("married" as ref)				P<.001
Unmarried	1.467	1.282	1.679	P<.001
Divorced	1.474	0.870	2.497	P=.149
Widowed	1.390	0.121	15.909	P=.791
Educational status ("secondary school or below" as ref)				P<.001
High school	0.883	0.658	1.184	P=.404
College or equivalent	0.835	0.637	1.093	P=.189
Master's Diploma or above	1.357	0.952	1.934	P=.091
Annual household income (USD 1,000) ("<7.5" as ref)				P<.001
7.5-15	0.669	0.541	0.827	P<.001
15-22.5	0.666	0.533	0.831	P<.001
22.5-30	0.442	0.344	0.569	P<.001
30-75	0.447	0.334	0.598	P<.001
75 or more	0.475	0.311	0.727	P=.001
Chronic diseases history	0.650	0.537	0.786	P<.001
Self-assessment of health status ("very bad" as ref)				P<.001
bad	0.943	0.598	1.486	P=.799
general	0.787	0.580	1.067	P=.123
well	0.429	0.315	0.585	P<.001
Very well	0.292	0.213	0.402	P<.001
Functional scale	0.548	0.474	0.634	P<.001
Interactive scale	0.683	0.478	0.975	P=.036
Critical scale	0.633	0.443	0.903	P=.012

a. aOR is the abbreviation of adjusted odds ratio;

b. CI is the abbreviation of the confidence interval.

Supplementary Table S12. The association between vaccine hesitancy and vaccine literacy in pneumonia vaccine acceptance subgroup

Variables	aOR [a]	95% CI [b]		p-value
		Lower	Upper	
Sex	0.778	0.617	0.981	P=.034
Marital status ("married" as ref)				P<.001
Unmarried	1.837	1.457	2.317	P<.001
Divorced	2.579	1.150	5.781	P=.021
Widowed	0.626	0.035	11.177	P=.750
Healthcare occupation	0.691	0.538	0.887	P=.004
Chronic diseases history	0.553	0.414	0.739	P<.001
Self-assessment of health status ("very bad" as ref)				P<.001
bad	2.582	1.278	5.215	P=.008
general	1.091	0.673	1.771	P=.732
well	0.618	0.378	1.010	P=.055
Very well	0.330	0.203	0.535	P<.001
Functional scale	0.419	0.326	0.539	P<.001
Critical scale	0.506	0.392	0.652	P<.001

a. aOR is the abbreviation of adjusted odds ratio;

b. CI is the abbreviation of the confidence interval.

Supplementary Table S13. The association between vaccine hesitancy and vaccine literacy in COVID-19 vaccine and COVID-19 booster vaccine acceptance subgroup

Vaccine	Variables		aOR [a]	95% CI [b]		p-value
				Lower	Upper	
Covid-19 vaccine	**Age group**	**("18-24 years" as ref)**				P=.024
		25-34 years	0.997	0.882	1.126	P=.957
		35-44 years	0.989	0.849	1.152	P=.886
		45-54 years	0.779	0.636	0.953	P=.015
		55-64 years	0.655	0.435	0.984	P=.042
		≥65 years	0.609	0.272	1.360	P=.226
	Marital status ("married" as ref)					P<.001
		Unmarried	1.276	1.136	1.433	P<.001
		Divorced	1.345	0.949	1.906	P=.096
		Widowed	3.067	0.943	9.977	P=.063
	Educational status ("secondary school or below" as ref)					P<.001
		High school	0.900	0.732	1.107	P=.318
		College or equivalent	0.748	0.617	0.907	P=.003
		Master's Diploma or above	1.178	0.921	1.507	P=.191
	Healthcare occupation		0.895	0.811	0.988	P=.028
	Annual household income (USD 1,000) ("<7.5" as ref)					P<.001
		7.5-15	0.738	0.633	0.860	P<.001
		15-22.5	0.738	0.630	0.865	P<.001

	22.5-30	0.554	0.466	0.660	P<.001
	30-75	0.503	0.412	0.613	P<.001
	75 or more	0.558	0.410	0.759	P<.001
	Chronic diseases history	0.563	0.494	0.642	P<.001
	Self-assessment of health status ("very bad" as ref)				P<.001
	bad	1.158	0.844	1.588	P=.362
	general	0.883	0.707	1.103	P=.273
	well	0.493	0.393	0.617	P<.001
	Very well	0.324	0.258	0.408	P<.001
	Functional scale	0.579	0.524	0.640	P<.001
	Interactive scale	0.457	0.417	0.501	P<.001
Covid-19 vaccine booster	**Age group ("18-24 years" as ref)**				P=.043
	25-34 years	1.016	0.890	1.160	P=.811
	35-44 years	0.998	0.846	1.177	P=.979
	45-54 years	0.818	0.658	1.017	P=.071
	55-64 years	0.686	0.446	1.056	P=.087
	≥65 years	0.333	0.109	1.016	P=.053
	Sex	0.878	0.798	0.967	P=.008
	Marital status ("married" as ref)				P<.001
	Unmarried	1.381	1.220	1.564	P<.001
	Divorced	1.635	1.150	2.325	P=.006
	Widowed	4.799	1.154	19.951	P=.031
	Educational status ("secondary school or below" as ref)				P<.001
	High school	0.771	0.617	0.965	P=.023
	College or equivalent	0.608	0.495	0.748	P<.001
	Master's Diploma or above	0.978	0.752	1.272	P=.867
	Healthcare occupation	0.800	0.720	0.889	P<.001
	Annual household income (USD 1,000) ("<7.5" as ref)				P<.001
	7.5-15	0.780	0.657	0.925	P=.004
	15-22.5	0.764	0.641	0.910	P=.003
	22.5-30	0.574	0.474	0.695	P<.001
	30-75	0.538	0.433	0.670	P<.001
	75 or more	0.606	0.433	0.849	P=.004
	Chronic diseases history	0.501	0.438	0.572	P<.001
	Self-assessment of health status ("very bad" as ref)				P<.001
	bad	1.426	1.021	1.993	P=.038
	general	0.973	0.769	1.230	P=.817
	well	0.564	0.444	0.715	P<.001
	Very well	0.372	0.292	0.474	P<.001
	Functional scale	0.553	0.497	0.617	P<.001
	Interactive scale	0.630	0.489	0.811	P<.001
	Critical scale	0.720	0.559	0.927	P=.011

a. aOR is the abbreviation of adjusted odds ratio;

b. CI is the abbreviation of the confidence interval.

Supplementary Table S14. The association between vaccine hesitancy and vaccine literacy in hepatitis B vaccine acceptance subgroup

Variables	aOR [a]	95% CI [b]		p-value
		Lower	Upper	
Marital status ("married" as ref)				P<.001
Unmarried	1.578	1.372	1.815	P<.001
Divorced	1.402	0.877	2.243	P=.158
Widowed	1.824	0.338	9.843	P=.484
Educational status ("secondary school or below" as ref)				P<.001
High school	0.807	0.577	1.129	P=.211
College or equivalent	0.629	0.465	0.851	P=.003
Master's Diploma or above	0.841	0.588	1.203	P=.343
Chronic diseases history	0.444	0.373	0.529	P<.001
Self-assessment of health status ("very bad" as ref)				P<.001
bad	1.505	0.935	2.423	P=.092
general	0.998	0.712	1.400	P=.991
well	0.543	0.385	0.766	P<.001
Very well	0.365	0.256	0.519	P<.001
Functional scale	0.520	0.446	0.605	P<.001
Interactive scale	0.662	0.473	0.925	P=.016
Critical scale	0.660	0.472	0.923	P=.015

a. aOR is the abbreviation of adjusted odds ratio;

b. CI is the abbreviation of the confidence interval.

Supplementary Table S15. The association between vaccine hesitancy and vaccine literacy in herpes zoster vaccine acceptance subgroup

Variables	aOR [a]	95% CI [b]		p-value
		Lower	Upper	
Marital status ("married" as ref)				P=.003
Unmarried	2.073	1.407	3.053	P<.001
Divorced	1.046	0.152	7.195	P=.964
Widowed	0.562	0.037	8.552	P=.678
Chronic diseases history	0.434	0.273	0.690	P<.001
Self-assessment of health status ("very bad" as ref)				P<.001
bad	1.443	0.469	4.443	P=.523
general	0.565	0.252	1.266	P=.165
well	0.328	0.146	0.736	P=.007
Very well	0.141	0.061	0.326	P<.001
Functional scale	0.383	0.250	0.586	P<.001
Critical scale	0.582	0.375	0.903	P=.016

a. aOR is the abbreviation of adjusted odds ratio;

b. CI is the abbreviation of the confidence interval.