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Research paper

The association between lifestyle and COVID-19 vaccine hesitancy in China: A large-scale cross-sectional survey

Jian Wu [a,b], Dongyang Xu [a,b], Quanman Li [a,b], Clifford Silver Tarimo [a,b,g], Meiyun Wang [c], Jianqin Gu [d], Wei Wei [c], Xinyu Zhang [e], Yanli Huang [f], Mingze Ma [a,b], Lipei Zhao [a,b], Zhanlei Shen [a,b], Yudong Miao [a,b,*]

[a] Department of Health management, College of Public Health, Zhengzhou University, Zhengzhou, China
[b] Henan Province Engineering Research Center of Health Economy & Health Technology Assessment, Zhengzhou, China
[c] Henan Provincial People's Hospital, People's Hospital of Zhengzhou University, Zhengzhou, China
[d] School of Medicine, Southern University of Science and Technology, Shenzhen, China
[e] School of Public Health, Tianjin Medical University, Tianjin, China
[f] Manage and Service Center of Wuhou Medical Institutes, Chengdu, China
[g] Department of Science and Laboratory Technology, Dar es salaam Institute of Technology, Dar es Salaam, Tanzania

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ABSTRACT

Objective: To assess the association between lifestyle and COVID-19 vaccine hesitancy among Chinese adults and provide recommendations for increasing vaccination rates.
Methods: From August 6, 2021 to August 9, 2021, we recruited 29,925 participants from 31 Chinese provinces via an online questionnaire. We designed a question to assess COVID-19 vaccine hesitancy and used 16 items to assess lifestyle by calculating lifestyle scores. Odds ratios (OR) with 95 % confidence intervals (CI) were used to estimate the association by using binary logistic regression models.
Results: The overall prevalence of COVID-19 vaccine hesitancy was 8.40 % (95 % CI: 8.09–8.72), and the median lifestyle score was 65.00 (interquartile range: 59.00–71.00). After adjusting for potential confounders, the COVID-19 vaccine hesitancy rate decreased significantly with an increase in lifestyle score (P for Trend <0.001). Low COVID-19 vaccine hesitancy rate was associated with lifestyle factors including adequate sleep, never smoking, intermittent drinking, good relationships, working and studying, using hand sanitizer, wearing masks, less gathering activities, and keeping social distance ($P < 0.05$).
Conclusion: Our findings indicate that high lifestyle score is associated with low vaccine hesitancy rate among Chinese. The government should view the smokers (or the drinkers) as the key to further boosting the vaccination rate. In addition, the publicity and education about wearing masks and keeping social distance should be prioritized.

1. Introduction

As the number of confirmed cases of novel coronavirus disease (COVID-19) increases around the world, the global disease burden caused by a pandemic has become extremely severe. As of November 23, 2021, the total number of confirmed cases worldwide was close to 256 million, and the death toll was over 5.1 million (WHO, 2021). As an economical and effective scientific means, the research and implementation of COVID-19 vaccine were very important for the prevention and elimination of diseases (Jentsch et al., 2021; Yamey et al., 2020). Since the outbreak, scientists around the world have developed vaccines for this fatal disease at an unprecedented rate (Le et al., 2020). At least 44 candidate COVID-19 vaccines are currently being tested in clinical trials around the world, including inactivated vaccines, recombinant protein vaccines, adenovirus vector vaccines, attenuated influenza virus vector vaccines and nucleic acid (mRNA and DNA vaccines) vaccines (Hodgson et al., 2021). The safe and effective vaccine is highly expected in the treatment of COVID-19.

In addition to the effectiveness of the vaccine, the acceptance rate of the vaccine is also critical for preventing the spread of COVID-19 (Utazi

* Corresponding author at: College of Public Health, Zhengzhou University, 100, Science Avenue, Gaoxin District, Zhengzhou 450001, China.
E-mail address: meldon@zzu.edu.cn (Y. Miao).

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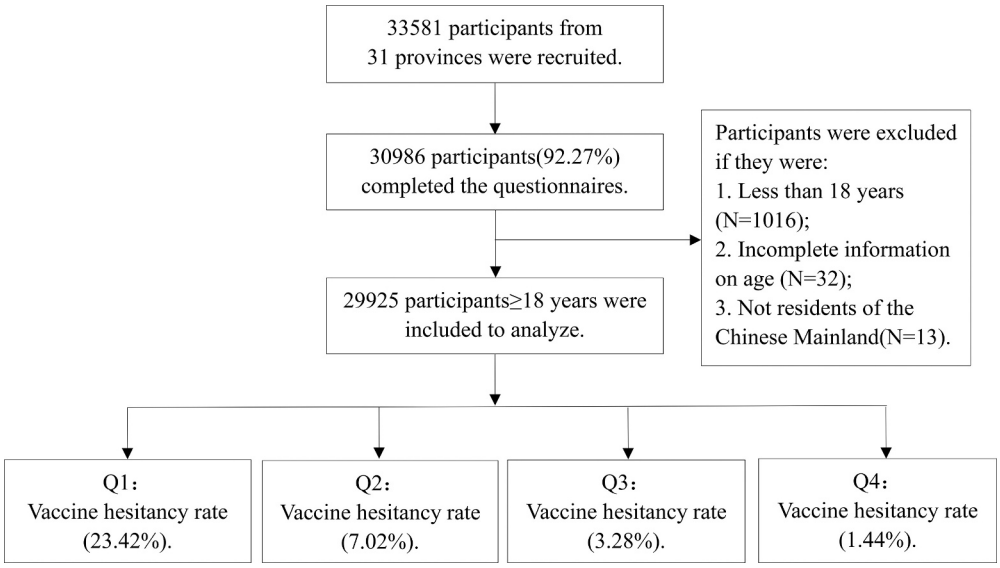

Fig. 1. The flowchart of participants selection.

et al., 2019). Although vaccines are regarded as safe, vaccine hesitancy has become a significant barrier to increasing vaccination rates (Majeed and Molokhia, 2020; Lane et al., 2018). In 2019, the World Health Organization (WHO) listed vaccine hesitancy as one of the top 10 threats to global health (WHO, 2019). According to the Strategic Advisory Group on Immunization (SAGE), vaccine hesitancy refers to "delays in receiving or refusing vaccination despite the provision of vaccination services" (MacDonald and Hesitancy, 2015). The reasons for vaccine hesitancy are complex, previous studies have shown that key determinants of accepting or rejecting vaccines include awareness of disease risks, concerns about vaccine safety, trust (mistrust) in institutions and health care providers, and different socio-demographic characteristics (such as age, sex, income, education level) (Dror et al., 2020; Fisher et al., 2020; Freeman et al., 2020; Palamenghi et al., 2020; Yaqub et al., 2014).

The reasons for COVID-19 vaccine hesitancy are also extremely complex (Arce et al., 2021; Wouters et al., 2021). A study in France pointed out that the age, sex, education level and chronic diseases of the participants were closely related to COVID-19 vaccination behavior (Schwarzinger et al., 2021). In addition, an Australian study revealed a correlation between inadequate health literacy and refusal to get the COVID-19 vaccine (Dodd et al., 2021).

There is evidence that improper mask use during the COVID-19 outbreak was a significant factor in the population's increased anxiety risk (Li et al., 2021; Wang et al., 2020). This suggests that a link exists between lifestyle and mental health. However, it has not been established whether there is an association between lifestyle and COVID-19 vaccine hesitancy, hence we conducted a large-scale cross-sectional study in China to explore the association.

2. Methods

2.1. Participants and procedures

A subsequent national cross-sectional online survey using a snowball sampling approach among Chinese adults (≥18 years old) was conducted from 6th to 9th August 2021 by a market research company. Details of participants and procedures have been reported previously (Wu et al., 2021). In order to ensure that the sample size for this study was sufficient for estimating the prevalence of vaccine hesitancy, we measured the sample saturation during the survey. In this study, saturation refers to the point at which the sample size reaches a certain size, at which the vaccine hesitancy rate becomes constant and no longer changes considerably with the snowballing sample size growth. We found that when the number of valid questionnaires reached 21,780, the samples became saturated (Supplementary Fig. 1). We ended the online survey when the valid sample reached 29,925 on August 9, 2021.The flowchart of participants selection was shown in Fig. 1.

2.2. Assessments

Due to the absence of a uniform COVID-19 vaccine hesitancy scale in China, we designed a question to assess vaccine hesitancy based on the Oxford COVID-19 Vaccine Hesitancy Scale (Freeman et al., 2021). That was "In terms of primary COVID-19 vaccination in current stage, I would describe myself as" for estimating COVID-19 vaccine hesitancy rate. For this question, response options coded from 1 to 5 were used, including (1) Vaccination, (2) Willing to get the COVID-19 vaccine, (3) Delay to getting the COVID-19 vaccine, (4) Unwilling to get the COVID-19 vaccine, and (5) Anti-vaccination. Higher scores indicated a higher level of vaccine hesitancy. According to the definition of vaccine hesitancy, we combined options (1) and (2) into "acceptance" and options (3), (4), and (5) into "hesitancy".

We used 16 items to assess lifestyle, which includes healthy lifestyle (weight, diet, physical activities, sleep, smoking, drinking, psychological stress, relationships, work and study, and physical examination) and COVID-19 transmission interruption behavior (handwashing, using hand sanitizer, wearing masks, participation in gathering activities, time spent at home, and keeping social distance). The total lifestyle score ranged from 16 to 80, and there were five options for each item, each with a score of 1 to 5. The higher score, the healthier lifestyle. We divided lifestyle scores into quartiles to represent various health levels. The Cronbach's α value and Kaiser Meyer Olkin (KMO) value of the questionnaire were 0.827 and 0.878 respectively.

2.3. Statistical analysis

Frequencies and percentages were reported for categorical variables and medians and interquartile ranges (IQRs) for continuous variables. Chi-square goodness-of-fit test was used to monitor the sample saturation of the whole online survey to determine sample underrepresentation error. The Chi-square test was conducted to examine differences in COVID-19 vaccination hesitancy between groups. Binary Logistic regression was used to analyze the association between lifestyle and COVID-19 vaccine hesitancy. The collinearity test was carried out to assess the correlation between independent variables using a variance

Table 1
Socio-demographic, COVID-19 vaccine hesitancy and lifestyle score of all study participants.

Covariates	Total (%)	Vaccine hesitancy (95 % CI)	*P*-value[a]	Lifestyle score (IQR)	Quartile of lifestyle score, n (%)			
					Q1 (20–59 points)	Q2 (60–65 points)	Q3 (66–71 points)	Q4 (72–80 points)
Total participants	29,925 (100)	8.40 (8.09–8.72)		65.00 (59.00–71.00)[b]	6998 (100)	7133 (100)	7956 (100)	7838 (100)
Sex			<0.001					
Men	14,556 (48.64)	11.55 (8.50–16.15)		64.00 (57.00–69.00)[b]	4324 (61.79)	3555 (49.84)	3490 (43.87)	3187 (40.66)
Women	15,369 (51.36)	5.42 (5.06–5.78)		67.00 (61.00–72.00)[b]	2674 (38.21)	3578 (50.16)	4466 (56.13)	4651 (59.34)
Age (years)			<0.001					
18–29	13,312 (44.48)	10.84 (10.31–11.37)		63.00 (57.00–69.00)[b]	3942 (56.33)	3541 (49.64)	3234 (40.65)	2595 (33.11)
30–39	11,911 (39.80)	6.73 (6.28–7.18)		67.00 (61.00–72.00)[b]	2218 (31.69)	2552 (35.78)	3301 (41.49)	3840 (48.99)
40–49	3269 (10.92)	4.68 (3.96–5.40)		67.00 (61.00–72.00)[b]	534 (7.63)	723 (10.14)	965 (12.13)	1047 (13.36)
50–59	1149 (3.84)	7.05 (5.57–8.53)		66.00 (61.00–71.00)[b]	227 (3.24)	250 (3.50)	381 (4.79)	291 (3.71)
≥60	284 (0.95)	12.32 (5.57–8.53)		64.00 (58.00–70.00)[b]	77 (1.10)	67 (0.94)	75 (0.94)	65 (0.83)
Ethnic groups			<0.001					
Han	28,579 (95.50)	7.76 (7.45–8.07)		65.00 (59.00–71.00)[b]	6364 (90.94)	6869 (96.30)	7693 (96.69)	7653 (97.64)
Minority	1346 (4.50)	21.92 (19.71–24.13)		60.00 (53.00–67.00)[b]	634 (9.06)	264 (3.70)	263 (3.31)	185 (2.36)
Religion			<0.001					
Atheist	25,424 (84.96)	6.44 (6.14–6.74)		66.00 (60.00–71.00)[b]	5302 (75.76)	6161 (86.37)	6983 (87.77)	6978 (89.03)
Others	4501 (15.04)	19.46 (18.31–20.62)		62.00 (55.00–69.00)[b]	1696 (24.24)	972 (13.63)	973 (12.23)	860 (10.97)
Marital status			<0.001					
Married	18,363 (61.36)	6.42 (6.06–6.77)		67.00 (61.00–72.00)[b]	3368 (48.13)	3896 (54.62)	5211 (65.50)	5888 (75.12)
Others	11,562 (38.64)	11.56 (10.97–12.14)		62.00 (57.00–68.00)[b]	3630 (51.87)	3237 (45.38)	2745 (34.50)	1950 (24.88)
Educational status			<0.001					
Below high school	3839 (12.83)	21.36 (20.06–22.66)		60.00 (54.00–68.00)[b]	1662 (23.75)	811 (11.37)	768 (9.65)	598 (7.63)
High school graduate	7893 (26.38)	8.40 (7.79–9.01)		66.00 (59.00–71.00)[b]	1828 (26.12)	1678 (23.52)	2115 (26.58)	2272 (28.99)
University graduate	18,193 (60.80)	5.67 (5.33–6.00)		66.00 (60.00–71.00)[b]	3508 (50.13)	4644 (65.11)	5073 (63.76)	4968 (63.38)
Subjective social status			<0.001					
Level 1	3618 (12.09)	6.88 (6.10–7.75)		62.00 (57.00–67.00)[b]	1190 (17.00)	1132 (15.87)	812 (10.21)	484 (6.18)
Level 2	15,552 (51.97)	7.61 (7.20–8.03)		65.00 (59.00–70.00)[b]	3634 (51.93)	4064 (56.97)	4181 (52.55)	3673 (46.86)
Level 3	10,755 (35.94)	10.06 (9.51–10.64)		67.00 (60.00–73.00)[b]	2174 (31.07)	1937 (27.16)	2963 (37.24)	3681 (46.96)
Residence			0.002					
Urban	24,142 (80.68)	9.39 (9.03–9.76)		65.00 (59.00–71.00)[b]	5703 (81.49)	5526 (77.47)	6374 (80.12)	6539 (83.43)
Rural	5783 (19.32)	4.27 (3.78–4.82)		64.00 (59.00–70.00)[b]	1295 (18.51)	1607 (22.53)	1582 (19.88)	1299 (16.57)
Co-residence			<0.001					
With household member(s)	28,764 (96.12)	8.34 (8.02–8.66)		65.00 (59.00–71.00)[b]	6636 (94.83)	6776 (95.00)	7694 (96.71)	7658 (97.70)
Alone	1161 (3.88)	9.99 (8.39–11.86)		62.00 (57.00–68.00)[b]	362 (5.17)	357 (5.00)	262 (3.29)	180 (2.30)
Medical insurance			<0.001					
Yes	28,983 (96.85)	8.18 (7.87–8.50)		65.00 (59.00–71.00)[b]	6621 (94.61)	6865 (96.24)	7749 (97.40)	7748 (98.85)
No	942 (3.15)	15.18 (13.03–17.62)		60.00 (55.00–66.00)[b]	377 (5.39)	268 (3.76)	207 (2.60)	90 (1.15)
BMI (kg/m^2)			<0.001					
<18.5	4449 (14.87)	11.78 (10.86–12.76)		64.00 (58.00–70.00)[b]	1242 (17.75)	1035 (14.51)	1080 (13.57)	1092 (13.93)
18.5–23.9	19,420 (64.90)	7.61 (7.25–7.99)		66.00 (60.00–71.00)[b]	4015 (57.37)	4552 (63.82)	5321 (66.88)	5532 (70.58)
24–27.9	4751 (15.88)	7.77 (7.04–8.56)		64.00 (58.00–69.00)[b]	1286 (18.38)	1182 (16.57)	1265 (15.90)	1018 (12.99)
≥28	1305 (4.36)	10.96 (9.37–12.77)		61.00 (56.00–67.00)[b]	455 (6.50)	364 (5.10)	290 (3.65)	196 (2.50)
			<0.001					

(*continued on next page*)

Table 1 (*continued*)

Covariates	Total (%)	Vaccine hesitancy (95 % CI)	*P*-value[a]	Lifestyle score (IQR)	Quartile of lifestyle score, n (%)			
					Q1 (20–59 points)	Q2 (60–65 points)	Q3 (66–71 points)	Q4 (72–80 points)
Number of chronic diseases								
0	24,960 (83.41)	5.48 (5.21–5.77)		66.00 (60.00–72.00)[b]	4728 (67.56)	5963 (83.60)	7007 (88.07)	7262 (92.65)
1–2	4636 (15.49)	23.02 (21.83–24.25)		60.00 (54.00–66.00)[b]	2101 (30.02)	1091 (15.30)	900 (11.31)	544 (6.94)
≥3	329 (1.10)	23.71 (19.41–28.62)		58.00 (53.00–64.00)[b]	169 (2.41)	79 (1.11)	49 (0.62)	32 (0.41)

Q, quartile. CI, confidence interval. IQR, interquartile range.
Level, We categorized the score of subjective social status by tertile as level 1 (0–4 points), level 2 (5–7 points), level 3 (8–10 points).
Chi-square tests for categorical variables.
[a] Differences between categories within each variable.
[b] The median lifestyle score (interquartile range) for variables.

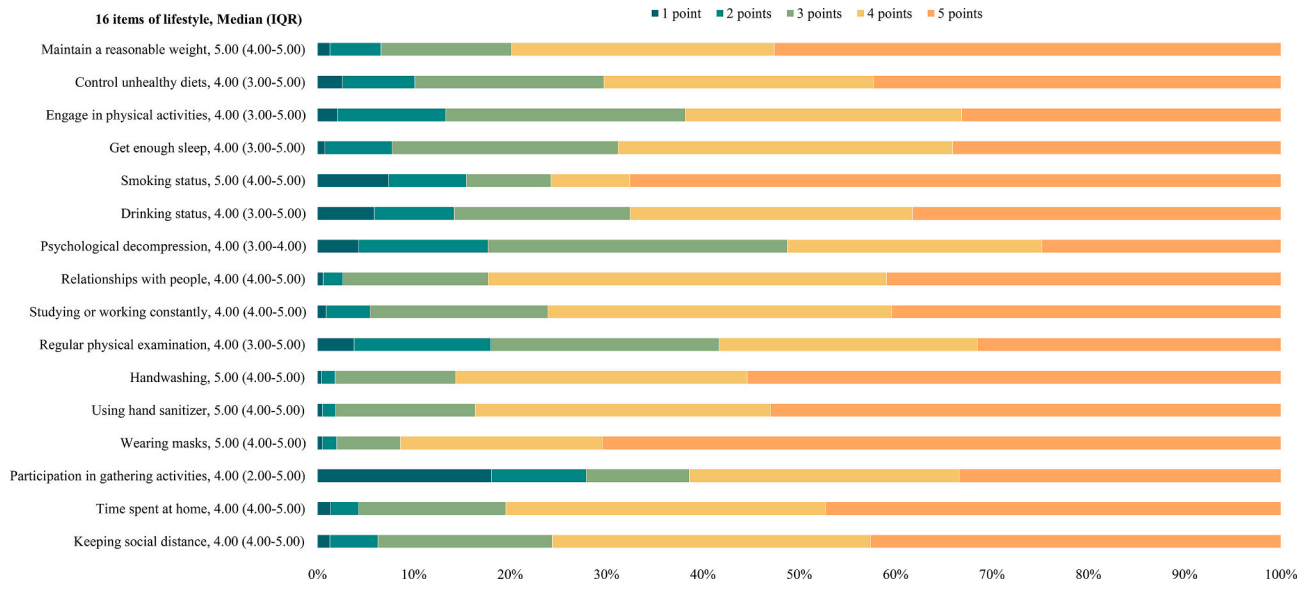

Fig. 2. The proportion of each item of lifestyle score.

inflation factor (VIF) <4, and no collinearity was detected. We did all statistical analysis using SPSS 21.0 Differences were regarded as statistically significant if *P*-value were less than 0.05.

3. Results

3.1. Characteristics of all study participants

Of all 29,925 participants (48.64 % men), a total of 2514 participants (8.40 %, 95 % CI: 8.09–8.72) hesitated to vaccinate. We found that men, the elderly (age ≥60 years), ethnic minorities, religious beliefs, unmarried, lower educational level, high subjective social status, urban, living alone, no medical insurance, underweight or obesity, people with chronic diseases had a higher COVID-19 vaccine hesitancy rate ($P < 0.05$) (Table 1). The median lifestyle score of the total population was 65.00 (IQR: 59.00–71.00). For quartile of lifestyle score, participants with high values were more likely to be women, to be married, to reside in urban, and to have higher education level and subjective social status. Quartile of healthy lifestyle score and COVID-19 transmission interruption behavior score are provided in Supplementary Table 1.

The specific scores of the 16 items of lifestyle were presented in Fig. 2. There are five items with five points that account for more than fifty percent of the proportion of each item's score, including maintaining a reasonable weight, smoking status, hand washing, using hand

Table 2
The association of quartile of lifestyle score with COVID-19 vaccine hesitancy.

	Quartile of healthy lifestyle score				*P* for Trend
	Q1	Q2	Q3	Q4	
Total	6998	7133	7956	7838	
No. of cases (%)	1639 (23.42)	501 (7.02)	261 (3.28)	113 (1.44)	
Model 1	1.00 (ref.)	0.25 (0.22–0.27)	0.11 (0.10–0.13)	0.05 (0.04–0.06)	<0.001
Model 2	1.00 (ref.)	0.26 (0.24–0.29)	0.12 (0.11–0.14)	0.06 (0.05–0.07)	<0.001
Model 3	1.00 (ref.)	0.35 (0.31–0.39)	0.17 (0.15–0.20)	0.08 (0.07–0.10)	<0.001

Q, quartile.
Model 1, Unadjusted.
Model 2, Adjusted for sex and age (18–29, 30–39, 40–49, 50–59, and ≥60 years).
Model 3, Model 2 plus additional adjustment for the ethnic groups (Han and minority), religion (atheist and others), marital status (married and others), educational status (below high school, high school graduate and university graduate), subjective social status (level 1, level 2 and level 3), and residence (urban and rural), co-residence (with household member(s) and alone), medical insurance (yes and no), BMI (<18.5, 18.5–23.9, 24–27.9 and ≥28), number of chronic diseases (0, 1–2 and ≥3).

Table 3
The association of 16 items of lifestyle with COVID-19 vaccine hesitancy.

16 items of lifestyle	Model 1	*P*-value	Model 2	*P*-value	Model 3	*P*-value
1. Do you maintain a reasonable weight?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	1.05 (0.69–1.59)	0.825	1.05 (0.69–1.59)	0.827	0.97 (0.64–1.47)	0.895
Sometimes	1.07 (0.72–1.59)	0.722	1.07 (0.72–1.59)	0.738	0.96 (0.65–1.43)	0.846
Often	0.94 (0.63–1.39)	0.746	0.95 (0.64–1.41)	0.803	0.89 (0.60–1.32)	0.567
Always	0.87 (0.59–1.29)	0.488	0.87 (0.59–1.29)	0.485	0.89 (0.60–1.32)	0.552
P for Trend	0.004		0.005		0.08	
2. Do you control unhealthy diets such as high salt and fat?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	1.19 (0.85–1.66)	0.318	1.20 (0.86–1.69)	0.279	1.16 (0.83–1.63)	0.389
Sometimes	1.21 (0.88–1.68)	0.238	1.24 (0.90–1.71)	0.187	1.16 (0.84–1.61)	0.367
Often	1.08 (0.78–1.50)	0.634	1.13 (0.82–1.56)	0.467	1.06 (0.76–1.47)	0.726
Always	0.99 (0.71–1.38)	0.947	1.04 (0.74–1.44)	0.838	1.03 (0.74–1.44)	0.853
P for Trend	0.036		0.077		0.203	
3. Do you engage in light or moderate physical activity?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	0.76 (0.56–1.02)	0.070	0.78 (0.57–1.05)	0.100	0.78 (0.58–1.06)	0.118
Sometimes	0.78 (0.59–1.05)	0.100	0.80 (0.60–1.07)	0.138	0.83 (0.62–1.11)	0.208
Often	0.82 (0.61–1.10)	0.183	0.84 (0.62–1.12)	0.233	0.87 (0.64–1.17)	0.361
Always	0.81 (0.60–1.11)	0.189	0.83 (0.61–1.13)	0.237	0.86 (0.63–1.18)	0.358
P for Trend	0.877		0.906		0.945	
4. Do you get enough sleep?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	0.49 (0.34–0.72)	<0.001	0.49 (0.34–0.72)	<0.001	0.57 (0.39–0.85)	0.005
Sometimes	0.43 (0.30–0.61)	<0.001	0.43 (0.30–0.62)	<0.001	0.50 (0.34–0.73)	<0.001
Often	0.39 (0.27–0.57)	<0.001	0.40 (0.28–0.57)	<0.001	0.46 (0.32–0.67)	<0.001
Always	0.40 (0.27–0.57)	<0.001	0.40 (0.27–0.58)	<0.001	0.46 (0.32–0.68)	<0.001
P for Trend	<0.001		<0.001		<0.001	
5. What is your smoking status?						
Always	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Often	0.96 (0.79–1.17)	0.706	0.96 (0.78–1.17)	0.656	0.89 (0.73–1.09)	0.253
Sometimes	1.08 (0.88–1.32)	0.457	1.09 (0.89–1.33)	0.400	1.03 (0.84–1.26)	0.776
Little	0.98 (0.79–1.21)	0.842	0.97 (0.79–1.20)	0.789	0.96 (0.78–1.19)	0.734
Never	0.50 (0.41–0.60)	<0.001	0.51 (0.42–0.62)	<0.001	0.56 (0.46–0.69)	<0.001
P for Trend	<0.001		<0.001		<0.001	
6. What is your drinking status?						
Always	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Often	0.82 (0.67–1.01)	0.060	0.82 (0.67–1.01)	0.062	0.84 (0.68–1.04)	0.103
Sometimes	0.72 (0.58–0.88)	0.001	0.71 (0.58–0.87)	0.001	0.78 (0.64–0.96)	0.021
Little	0.61 (0.50–0.75)	<0.001	0.61 (0.50–0.76)	<0.001	0.71 (0.57–0.88)	0.002
Never	0.61 (0.49–0.76)	<0.001	0.63 (0.51–0.79)	<0.001	0.73 (0.59–0.92)	0.007
P for Trend	<0.001		<0.001		<0.001	
7. Do you pay attention to psychological decompression in your life?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	0.89 (0.70–1.14)	0.369	0.90 (0.70–1.15)	0.392	0.88 (0.69–1.13)	0.306
Sometimes	0.86 (0.68–1.08)	0.194	0.86 (0.68–1.09)	0.213	0.82 (0.65–1.04)	0.110
Often	0.93 (0.73–1.18)	0.537	0.93 (0.73–1.19)	0.585	0.86 (0.67–1.09)	0.216
Always	1.09 (0.84–1.42)	0.498	1.08 (0.83–1.39)	0.582	1.00 (0.77–1.30)	0.985
P for Trend	0.023		0.028		0.229	
8. How is your relationship with people around you?						
Very bad	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
No good	0.81 (0.54–1.21)	0.301	0.78 (0.52–1.17)	0.228	0.75 (0.49–1.13)	0.167
General	0.53 (0.36–0.77)	0.001	0.53 (0.36–0.77)	0.001	0.58 (0.39–0.86)	0.006
Good	0.40 (0.27–0.58)	<0.001	0.40 (0.27–0.58)	<0.001	0.46 (0.31–0.68)	<0.001
Very good	0.26 (0.17–0.38)	<0.001	0.27 (0.18–0.39)	<0.001	0.31 (0.21–0.47)	<0.001
P for Trend	<0.001		<0.001		<0.001	
9. Are you studying or working constantly?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	1.26 (0.86–1.86)	0.237	1.23 (0.83–1.82)	0.297	1.21 (0.82–1.81)	0.336
Sometimes	0.93 (0.64–1.35)	0.694	0.89 (0.61–1.30)	0.557	0.92 (0.63–1.35)	0.683
Often	0.69 (0.47–1.01)	0.055	0.66 (0.45–0.96)	0.032	0.68 (0.46–1.00)	0.049
Always	0.66 (0.45–0.97)	0.033	0.63 (0.43–0.93)	0.019	0.65 (0.44–0.97)	0.035

(*continued on next page*)

Table 3 (*continued*)

16 items of lifestyle	Model 1	*P*-value	Model 2	*P*-value	Model 3	*P*-value
P for Trend	<0.001		<0.001		<0.001	
10. Do you have regular health physical examination?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	1.19 (0.91–1.56)	0.201	1.19 (0.91–1.55)	0.205	1.20 (0.92–1.58)	0.177
Sometimes	1.33 (1.03–1.73)	0.031	1.37 (1.06–1.78)	0.018	1.36 (1.05–1.78)	0.021
Often	1.41 (1.08–1.85)	0.011	1.47 (1.13–1.93)	0.005	1.43 (1.09–1.88)	0.010
Always	1.64 (1.24–2.18)	0.001	1.73 (1.31–2.29)	<0.001	1.65 (1.24–2.19)	<0.001
P for Trend	<0.001		<0.001		<0.001	
11. Has your frequency of handwashing changed compared with that before COVID-19 epidemic?						
Significantly decreased	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Decreased	1.75 (1.05–2.92)	0.032	1.75 (1.05–2.92)	0.033	1.70 (1.01–2.84)	0.045
No significant change	1.25 (0.77–2.03)	0.359	1.26 (0.78–2.04)	0.354	1.26 (0.78–2.06)	0.345
Increased	1.11 (0.69–1.80)	0.663	1.12 (0.69–1.82)	0.645	1.14 (0.70–1.85)	0.610
Significantly increased	0.92 (0.56–1.50)	0.743	0.94 (0.58–1.55)	0.822	0.95 (0.58–1.56)	0.848
P for Trend	<0.001		<0.001		<0.001	
12. Has your frequency of using hand sanitizer (soap) changed compared with that before COVID-19 epidemic?						
Significantly decreased	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Decreased	0.88 (0.55–1.42)	0.608	0.85 (0.53–1.38)	0.515	0.95 (0.59–1.52)	0.819
No significant change	0.59 (0.38–0.91)	0.018	0.57 (0.37–0.89)	0.014	0.65 (0.42–1.01)	0.055
Increased	0.50 (0.32–0.77)	0.002	0.49 (0.31–0.76)	0.002	0.55 (0.35–0.86)	0.009
Significantly increased	0.41 (0.26–0.65)	<0.001	0.41 (0.26–0.65)	<0.001	0.47 (0.30–0.74)	0.001
P for Trend	<0.001		<0.001		<0.001	
13. Has your frequency of wearing masks changed compared with that before COVID-19 epidemic?						
Significantly decreased	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Decreased	1.07 (0.67–1.69)	0.784	1.09 (0.69–1.72)	0.720	1.08 (0.68–1.71)	0.759
No significant change	0.77 (0.50–1.19)	0.244	0.80 (0.52–1.23)	0.303	0.83 (0.53–1.28)	0.392
Increased	0.52 (0.34–0.80)	0.003	0.54 (0.35–0.83)	0.005	0.59 (0.38–0.91)	0.017
Significantly increased	0.37 (0.24–0.56)	<0.001	0.38 (0.24–0.58)	<0.001	0.44 (0.28–0.68)	<0.001
P for Trend	<0.001		<0.001		<0.001	
14. Has your frequency of participation in gathering activities changed compared with that before COVID-19 epidemic?						
Significantly increased	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Increased	1.07 (0.91–1.26)	0.420	1.07 (0.90–1.26)	0.446	1.07 (0.90–1.27)	0.425
No significant change	0.86 (0.73–1.03)	0.103	0.87 (0.73–1.04)	0.121	0.94 (0.79–1.12)	0.487
Decreased	0.42 (0.35–0.50)	<0.001	0.43 (0.36–0.51)	<0.001	0.50 (0.41–0.59)	<0.001
Significantly decreased	0.35 (0.29–0.42)	<0.001	0.35 (0.29–0.42)	<0.001	0.41 (0.34–0.50)	<0.001
P for Trend	<0.001		<0.001		<0.001	
15. Has your time spent at home changed compared with that before COVID-19 epidemic?						
Significantly decreased	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Decreased	1.38 (0.94–2.04)	0.098	1.37 (0.93–2.01)	0.113	1.44 (0.97–2.13)	0.071
No significant change	1.11 (0.77–1.59)	0.578	1.10 (0.77–1.58)	0.598	1.19 (0.82–1.72)	0.354
Increased	0.83 (0.58–1.19)	0.306	0.82 (0.57–1.18)	0.288	0.92 (0.63–1.33)	0.654
Significantly increased	0.77 (0.53–1.12)	0.172	0.76 (0.53–1.11)	0.154	0.82 (0.56–1.20)	0.312
P for Trend	<0.001		<0.001		<0.001	
16. Do you consciously increase social distancing compared with that before COVID-19 epidemic?						
Never	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Little	0.79 (0.56–1.10)	0.162	0.79 (0.57–1.11)	0.179	0.79 (0.56–1.12)	0.187
Sometimes	0.63 (0.46–0.87)	0.005	0.65 (0.47–0.89)	0.008	0.67 (0.48–0.93)	0.016
Often	0.58 (0.42–0.80)	0.001	0.59 (0.43–0.82)	0.002	0.60 (0.43–0.83)	0.002
Always	0.51 (0.37–0.71)	<0.001	0.52 (0.38–0.73)	<0.001	0.54 (0.38–0.75)	<0.001
P for Trend	<0.001		<0.001		<0.001	

Model 1, Unadjusted.
Model 2, Adjusted for sex and age (18–29, 30–39, 40–49, 50–59, and ≥60 years).
Model 3, Model 2 plus additional adjustment for the ethnic groups (Han and minority), religion (atheist and others), marital status (married and others), educational status (below high school, high school graduate and university graduate), subjective social status (level 1, level 2 and level 3), and residence (urban and rural), co-residence (with household member(s) and alone), medical insurance (yes and no), BMI (<18.5, 18.5–23.9, 24–27.9 and ≥28), number of chronic diseases (0, 1–2 and ≥3).

sanitizer, and wearing masks.

3.2. Association between lifestyle and COVID-19 vaccine hesitancy

Table 2 showed that the vaccine hesitancy rates of Q1 (first quartile of lifestyle score), Q2 (second quartile of lifestyle score), Q3 (third quartile of lifestyle score) and Q4 (fourth quartile of lifestyle score) were 23.42 % (95 % CI: 22.44–24.43), 7.02 % (95 % CI: 6.45–7.64), 3.28 % (95 % CI: 2.91–3.70), 1.44 % (95 % CI: 1.20–1.73), respectively. In model 3, compared with Q1, the OR value of Q2, Q3 and Q4 are (OR: 0.35, 95 % CI: 0.31–0.39), (OR: 0.17, 95 % CI: 0.15–0.20), (OR: 0.08, 95 % CI: 0.07–0.10), respectively. With the increase of lifestyle score, the

COVID-19 vaccine hesitancy rate decreased significantly (P for Trend<0.001). The scores of healthy lifestyle and COVID-19 transmission interruption behavior showed similar results (Supplementary Table 2).

3.3. Association between 16 items of lifestyle and COVID-19 vaccine hesitancy

In the binary logistic regression model among all study participants, the lifestyle factors associated with COVID-19 vaccine hesitancy were sleep, smoking status, drinking status, relationships with people, study or work constantly, regular physical examination, using hand sanitizer, wearing masks, participation in gathering activities, and keeping social distance. Detailed information was showed in Table 3.

4. Discussion

The current study explored the association between lifestyle and COVID-19 vaccine hesitancy in a large sample of 31 provinces of Chinese mainland. The rate of COVID-19 vaccine hesitancy among Chinese mainland residents was 8.40 %, and the median lifestyle score was 65.00 (IQR: 59.00–71.00). With the increase of lifestyle score, the vaccine hesitancy rate began to decline, and the hesitancy rate of Q4 (fourth quartile of lifestyle score) was 1.44 %.

Our findings indicated that there was a positive association between smoking and COVID-19 vaccine hesitancy rate (OR: 0.56, 95 % CI: 0.46–0.69, $P < 0.001$), which was consistent with the results of other studies. A study from Hong Kong showed that the current smokers are more hesitant to take COVID-19 vaccine (Luk et al., 2021), which suggests that people who never smoke have lower vaccine hesitancy rate. There was a similar pattern for drinking, people who never or rarely drank alcohol had a lower likelihood of vaccine hesitancy than those who drank alcohol frequently. Previous studies in the United States found that pandemic encouraged adult smoking and drinking behavior (Grossman et al., 2020; Pollard et al., 2020), whereas an increase in smoking and drinking behavior was also observed in China (Yan et al., 2020). Similarly, smoking and drinking have been identified as risk factors for numerous health outcomes. There is evidence that smoking is related to the severity and mortality due to COVID-19 (WHO, 2020), while people with drinking behavior are reported to be at greater risk of contracting novel coronavirus (Da et al., 2020). The Administration should target smokers and drinkers, reminding them of the health risks associated with their behaviors and their susceptibility to novel coronaviruses, while simultaneously promoting health promotion campaigns to reduce smoking and drinking rates.

The results showed that regular health physical examination was positively associated with COVID-19 vaccine hesitancy rate (OR:1.65, 95 % CI: 1.24–2.19, $P < 0.001$) , and those who had regular health physical examination were more likely to have vaccine hesitancy than those who never had regular health physical examination. We hypothesize that people who routinely undergo physical examinations would be more concerned with their health and vaccine side effects, resulting in a higher vaccine hesitancy rate.

Finally, we discovered a negative association between wearing masks and keeping social distance and COVID-19 vaccine hesitancy rate, which was consistent with previous research findings (Latkin et al., 2021). The reasons for this situation could be related to their anxiety. A Hong Kong study revealed that public anxiety increased following the outbreak (Kwok et al., 2021), so they will increase their protective measures (wearing masks, keeping social distance, etc.) and receive COVID-19 vaccine to reduce their anxiety. This suggests that the administration should continue to increase risk publicity to help people understand the need to continue to take preventative health measures, such as wearing masks, washing hands frequently, keeping social distance, and reducing gathering activities.

There is a large-scale study to assess COVID-19 vaccine hesitancy and related lifestyle factors in a large saturated sample of Chinese covering 31 provinces. Through this study, we learned about the real situation of the lifestyle of Chinese residents in the context of the outbreak of COVID-19, and established the association between lifestyle and COVID-19 vaccine hesitancy. One of the limitations of this study is that we used online surveys to collect information, so the findings should be treated with caution and only apply to people with Internet access. In addition, there is no universal scale to assess COVID-19 vaccine hesitancy in China, so we had to rely on self-reports of willingness to take COVID-19 vaccine to assess vaccine hesitancy. Given the significance of an accurate assessment of COVID-19 vaccine hesitancy in the prevention and control of epidemics, future research should concentrate on the development of a formal, unified vaccine hesitancy scale.

5. Conclusion

In general, the lifestyle score of Chinese residents is high, and there is a negative association between lifestyle score and COVID-19 vaccine hesitancy rate. To further reduce COVID-19 vaccine hesitancy rate, the government should target smokers and drinkers, as well as increase publicity and education about preventing the spread of COVID-19, such as wearing masks and keeping social distance.

CRediT authorship contribution statement

Conceptualization: Yudong Miao, Jian Wu, Quanman Li, Dongyang Xu, Meiyun Wang, Jianqin Gu.
Data curation: Yudong Miao, Dongyang Xu, Wei Wei, Quanman Li, Mingze Ma.
Formal analysis: Jian Wu, Yudong Miao, Dongyang Xu, Quanman Li.
Funding acquisition: Meiyun Wang, Jianqin Gu.
Investigation: Jian Wu, Yudong Miao, Xinyu Zhang, Yanli Huang, Quanman Li,
Mingze Ma, Lipei Zhao.
Methodology: Yudong Miao, Jian Wu, Dongyang Xu, Quanman Li.
Project administration: Jian Wu.
Resources: Jian Wu, Yudong Miao.
Software: Dongyang Xu, Quanman Li, Zhanlei Shen.
Writing – original draft: Jian Wu, Yudong Miao, Dongyang Xu.
Writing – review & editing: Yudong Miao, Clifford Silver Tarimo, Quanman Li, Meiyun Wang, Jianqin Gu.

Conflict of 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.

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Appendix A. Supplementary data

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