The Relationship Between Covid-19 Infection and Risk Perception, Knowledge, Attitude as Well As Four Non-Pharmaceutical Interventions (NPIs) During the Late Period of The Covid-19 Epidemic in China – An Online Cross-Sectional Survey Of 8158 Adults

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Abstract

Background: So far, there has been no published population study on the relationship between COVID-19 infection and public's risk perception, information source, knowledge, attitude and behaviours during the COVID-19 outbreak in China.

Objective: To understand the relationships between COVID-19 infection, four personal non-pharmaceutical interventions (NPIs) (hand washing, proper coughing habits, social distancing, and mask wearing) and public's risk perception, knowledge, attitude and other social demographic variables.

Methods: An online survey of 8158 Chinese adults between 22 February to 5 March 2020 was conducted. Bivariate associations between categorical variables were examined using Fisher exact test. We also explored the determinants of four NPIs as well as their association with COVID-19 infection using logistic regression.

Results: Of 8158 adults included, 57 (0.73%) were infected with COVID-19. The overwhelming majority of respondents showed a positive attitude (99.2%), positive risk perception (99.9%) and high knowledge levels that were among the strongest predictors of four highly adopted NPIs (hand washing:96.8%; proper coughing: 93.1%; social distancing:87.1%; mask wearing:97.9%). There was an increased risk of COVID-19 infection for those who not washing hands (2.28% vs 0.65%; RR=3.53: 95%CI: 1.53-8.15; P=0.009); not practicing proper coughing (1.79% vs 0.73%; RR=2.44: 95%CI: 1.15-5.15;P=0.026); not practicing social distancing (1.52% vs 0.58%; RR=2.63:95%CI:1.48 – 4.67; P=0.002); and not wearing a mask (7.41% vs 0.6%; RR=12.38:95%CI:5.81-26.36; P<0.001). For those who did practice all other three NPIs, wearing mask was associated with significantly reduced risk of infection compared to those who did not wear a mask (0.6% vs 16.7%; P=0.035). Similarly, for those who did not practice all or part of the other three NPIs, wearing mask was also associated with significantly reduced risk of infection. In a penalised logistic regression model including all four NPIs, wearing a mask was the only significant predictor of COVID-19 infection among four NPIs (OR=7.20; 95%CI:2.24-23.11; P<0.001).

Conclusions: We found high levels of risk perception, positive attitude, desirable knowledge as well as a high level of adopting four NPIs. The relevant knowledge, risk perception and attitude were strong predictors of adapting the four NPIs. Mask wearing, among four personal NPIs, was the most effective protective measure against COVID-19 infection with added preventive effect among those who practised all or part of the other three NPIs. Clinical Trial: N/A

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Abstract

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Findings: Of 8158 adults included, 57 (0.73%) were infected with COVID-19. The overwhelming majority of respondents showed a positive attitude (99.2%), positive risk perception (99.9%) and high knowledge levels that were among the strongest predictors of four highly adopted NPIs (hand washing: 96.8%; proper coughing: 93.1%; social distancing: 87.1%; mask wearing: 97.9%). There was an increased risk of COVID-19 infection for those who did not wash their hands (2.28% vs 0.65%; RR=3.53: 95%CI: 1.53-8.15; *P*=0.009); not practice proper coughing (1.79% vs 0.73%; RR=2.44: 95%CI: 1.15-5.15;*P*=0.026); not practice social distancing (1.52% vs 0.58%; RR=2.63:95%CI:1.48 – 4.67; *P*=0.002); and not wearing a mask (7.41% vs 0.6%; RR=12.38:95%CI:5.81-26.36; *P*<0.001). For those who did practice all other three NPIs, wearing a mask was associated with a significantly reduced risk of infection compared to those who did not wear a mask (0.6% vs 16.7%; *P*=0.035). Similarly, for those who did not practice all or part of the other three NPIs, wearing a mask was also associated with a significantly reduced risk of infection.

In a penalized logistic regression model including all four NPIs, wearing a mask was the only significant predictor of COVID-19 infection among four NPIs (OR=7.20; 95% CI:2.24-23.11; *P*<0.001).

Conclusions: We found high levels of risk perception, positive attitude, desirable knowledge as well as a high level of adopting four NPIs. The relevant knowledge, risk perception and attitude were strong predictors of adapting the four NPIs. Mask wearing, among four personal NPIs, was the most effective protective measure against COVID-19 infection with added preventive effect among those who practiced all or part of the other three NPIs.

Key words: COVID-19; non-pharmaceutical personal interventions; NPI; public health; mask wearing. China

Introduction

The unprecedented coronavirus disease of 2019 (COVID-19) global pandemic [1] has changed the way our society operates. The total confirmed cases and deaths globally increased at an alarming rate [2]. The availability of an effective vaccine may still be many months away [3 4] and there is also no consensus on the use of antiviral drugs and other therapeutic agents [5 6]. Meanwhile, the best hope for reducing mortality is societal preventative measures and providing timely and optimal critical care. As the list of countries in the grip of the rapid spread of COVID-19 is growing, many countries are, or will be, at the brink of further overwhelmed health care systems. Many countries have strengthened their non-pharmaceutical interventions (NPIs) in order to flatten the curve and reduce casualties [7]. For the NPIs to be effective, one of the critical conditions is the public's active participation and compliance. Since the lockdown of Wuhan City on 23 January 2019, China was the first country to introduce NPIs with strict measures such as the lockdown of cities and counties; compulsory mask wearing; isolation of suspicious cases; screening and contact tracing; quarantining people from high risk areas for 14 days; as well as promoting hand washing, proper coughing habits, social distancing and self-isolation. However, there was no published evidence on relationships between the COVID-19 infection, the Chinese public risk perception, information source, knowledge, attitude and personal NPIs during the middle to the end of the epidemic.

Between 22 February 2020 to 5 March 2020 (the late period of the COVID-19 epidemic in China) [2], we conducted an online cross-sectional survey of Chinese residents to: 1) understand risk perceptions, information source, knowledge, attitude and practice of the Chinese public after the COVID-19 outbreak; 2) explore the determinants associated with the key personal NPIs (i.e., hand washing, proper coughing habits, social distancing, mask wearing); 3) estimate the risks between the COVID-19 infection and the four NPIs; 4) understand potential risk compensating effects among four NPIs in relation to the COVID-19 infection (e.g. can wearing a mask further reduce the risk of

infection among those who do and do not practice the other three NPIs?).

Method

Study sample

We conducted an online survey between 22 February 2020 (with total confirmed cases of 77,000 and daily cases of 1,500) to 5 March 2020 (with a confirmed total case of 80,500 and daily cases of 151). Given that the whole of China was in lockdown during this period, it was almost impossible to conduct a random sample survey. We chose to conduct our study through the Chinese social media APP Wechat (similar to “WhatsApp”) and Weibo (similar to “Twitter”). We adopted a snow-balling sampling methodology through three social networks: 1) students and staff at Tongji Medical College and Chongqing Medical University; 2) Wanzhou District Centre for Disease Prevention and Control, Chongqing Municipality; 3) the study team. The inclusion criteria were: 1) the Chinese citizens who were currently living in Mainland China during the study period; 2) having a mobile phone or computer; 3) willing to answer all questions. The exclusion criteria were: 1) those who did not consent to participate; 2) those who did not answer all the questions; 3) the questionnaires completed in less than 2 minutes; 4) the repeated questionnaire from the same IP address. During the study period, the survey web page was browsed 21,673 times with a total of 8,431 questionnaires returned. After excluding those illegible questionnaires and those who were younger than 18 years old, the final study sample for the current study was 8,158.

The Ethics Committee of Chongqing Medical University approved our study protocol. There was an introduction document before the study questionnaire that provided the respondents with the background, aims and estimated time (10 minutes) for completing the survey. Respondents were asked for their agreement to participate in the study, to answer the questions faithfully, were assured

confidentiality and anonymity, and that no individual data would be disclosed. After the confirmation of their willingness to participate the study voluntarily, the participants were directed to complete the online questionnaire. We plan to disseminate the results to study participants whenever appropriate.

The roles of funding body: The funding bodies played no role in the study design, conduct, analysis, interpretation, and the decision to publish the results.

Measures

A multidisciplinary team of 11 experts were involved in the development of the survey instrument. The team included two epidemiologists, two sociologists, one administrative specialist, one statistician, one psychologist, and four post-graduate students. The research team initially had serial meetings to decide the research aims, methodology, as well as the responsibilities of all team members including their roles in the literature review and seeking ethics approval. The team then developed the survey instrument which included title, number and content of all sections as well as every question within a section through an iterative process which resulted in four major revisions of the first draft. The team also conducted two pilot tests. A group of 15 post-graduate students and staff members of the School of Public Health and Management of Chongqing Medical University participated in two testing pilots of the survey instrument (one test for the earlier version and one test for the near final version). As part of the pilot test, the group were asked a set of questions and then participated in an interview with one of the study team members. The interviews focused on both the survey questionnaires and the user friendliness of its application in the Webchat and Weibo. The discussions around the questionnaire were focused on the clarity of the questions; the readability of the questionnaire; the length of the survey; the overlapping and volume of questions amongst different sections; and the logic clarity between linked questions. The issues raised during the pilot testing were discussed during the team meetings and necessary revisions were made. The final

instrument included six sections and 79 questions in total including: 1) demographic information (16 questions); 2) knowledge and preventive behaviors of COVID-19 (two questions); 3) health status and related health behaviors (32 questions); 4) information source during the COVID-19 epidemic (seven questions); 5) perception and preparedness of the COVID-19 (15 questions); 6) satisfaction with the government's performance in containing the COVID-19 epidemic (six questions); and an open-ended question asking respondents to share their most important thoughts on the situation. A copy of the final questionnaire is attached (Appendix 1).

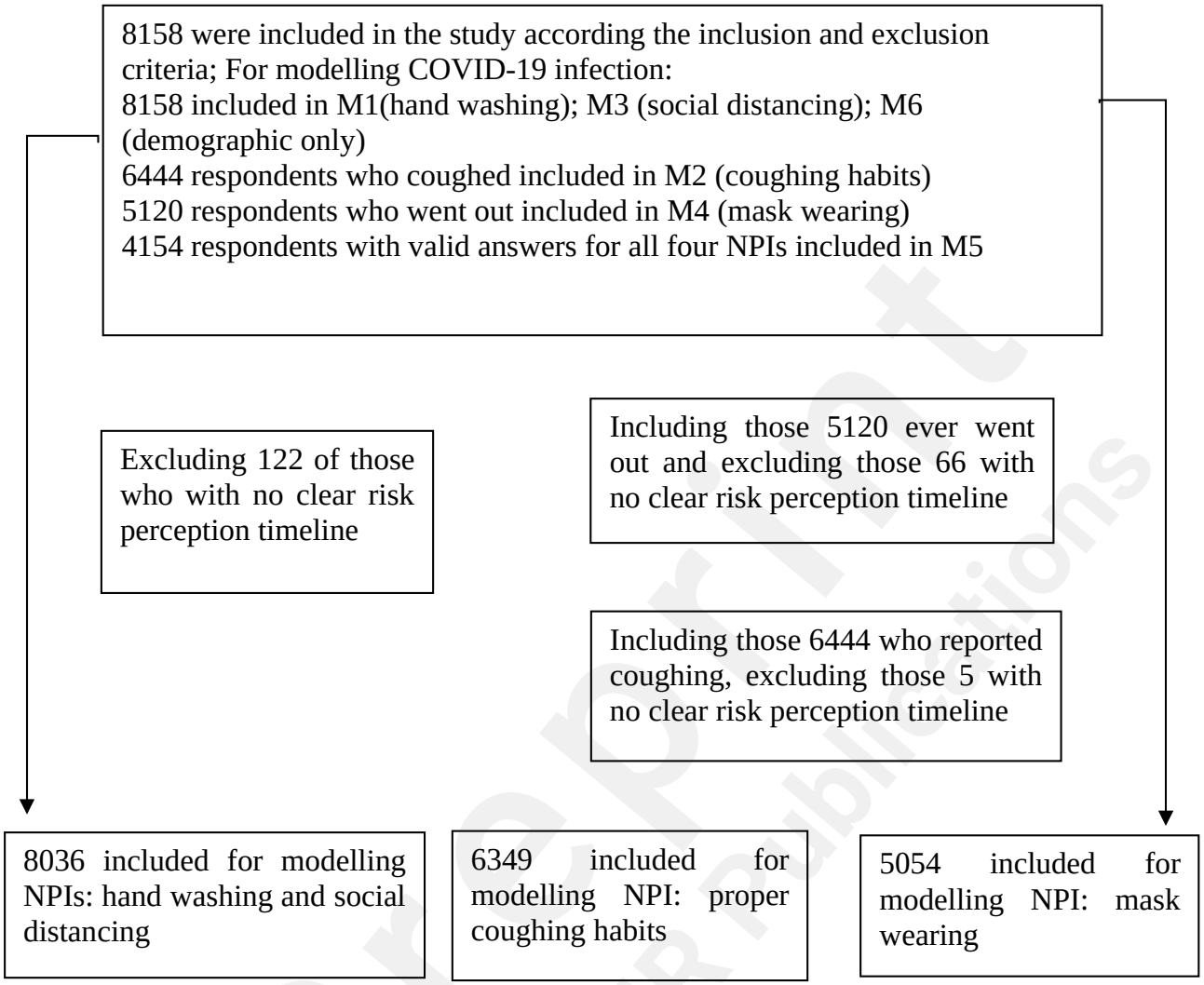
The final questions included in the current study were: 1) personal and family demographics: age, gender, location of residence, education, occupation, family monthly income, smoking habits during the last month (with over 100 cigarettes smoked over the lifetime), drinking alcohol during the last month, height and weight, been infected with COVID-19, marital status, if one of the family members is a health professional, the severity of the community infection where the respondent was living, if one of family members was part of local community efforts against COVID-19; 2) perceived risk, attitude, information source, knowledge and four NPIs and if the respondent had repeatedly used a mask; 3) self-isolation: if the respondents had a Chinese New Year party (2 days: 24-25th January 2020) with invited guests, the main reason a family member stayed home the longest; the main reason a family member often went out; the approach taken by the respondent when they went out (i.e., shorten the time to avoid infection / as usual / stay longer given the restrictions/uncertainty).

Statistical analysis

Frequencies of demographic, perceived risk, knowledge, attitude and four NPIs as well as self-isolation behaviors were described. The risks between the COVID-19 infection and four binary NPIs were tested using Fisher exact tests. The absolute risk difference, risk ratio and their 95% Confidence

Intervals were also presented. We modelled the four NPIs using logistic regression. The reasons that we also included proper coughing habit as an end point was that the habit may not only potentially reduce other people's risk of developing the COVID-19 infection but may also reduce a person's own risk through enhanced self-protection (e.g. turning away from those who did not practice proper coughing habit) or through indirectly influencing other people's coughing behavior as a role model. The predictors included the demographic characteristics, social economics status, family and social environment, perceived risk of situation, attitude (belief) and respective knowledge on the four NPIs. We explored the risk between the COVID-19 infection and four NPIs using a similar approach but excluded knowledge, attitude and risk perception of four NPIs based on a penalized maximum likelihood function logistic regression [8 9] which provides consistent estimates in situations of sparse event and total separation. The modelling results for four NPIs separately and combined (Model 1- Model 5) were compared to the results of the baseline model with only social demographic variables (Model 6). Risk ratio (RR), odds ratio (OR) and their 95% confidence intervals (CI) were presented where appropriate. We explored the potential risk compensating effects amongst the four NPIs through a pairwise NPIs comparison of infection rates and through the comparison of infection rates of wearing a mask across a combination of the other three NPIs. A flowchart of different sample sizes for the modelling of four NPIs and the COVID-19 infections was presented (Figure 1). The data management and statistical analysis were done through SPSS v25 and Stata™ v16. P value of less than 0.05 was considered as indicative of significance.

Figure 1: A flowchart of sample sizes for the modelling of 4 NPIs (Appendix 2: eTable 1) and COVID-19 infection (Table 4: Model 1 – Model 6)



Results

1. Infection rate of COVID-19 and social demographic of respondents

In total, 8,158 adults were included in the study and 57 (0.7%) infected with COVID-19. The respondents were predominantly female (63%), younger age groups (18-39 years old: 62%), living in the city (71.5%). Close to 45% of respondents had under-graduate and above education and close to

one-quarter were students (Table 1). The family income from the previous month had a large range (0-4,000,000 RMB) with close to 20% of them less than 2,000 RMB (approximately US$286 using an exchange rate of $1=7 RMB). Around 13% of respondents smoked and drank alcohol during the previous month. Over half of them had a normal Body Mass Index (BMI) [10]. Close to 72% of respondents had a partner and 54% were living with one. Close to 37% had a family member who was a health professional and 35% had a family member who was part of the local community efforts against COVID-19. Over 54% were from the area outside Hubei Province which had fewer than 100 cases, 42% from the areas outside Hubei Province which had more than 100 infected cases, 4% form Hubei Province, the epicenter of Chinese COVID-19 epidemic (Table 1).

Table1: The demographic characteristics of the study sample

Characteristics	N=8158	%
Age groups		
18-39 years	5017	61.5%
40-59 years	2902	35.6%
>=60 years	239	2.9%
Male (vs female)	3020	37.0%
Currently living in city (vs rural area)	5833	71.5%
Education		
Primary school	130	1.6%
High school	2040	25.0%
Professional college	2331	28.6%
University/post-graduate	3657	44.8%
Occupation		
Health professionals	1373	16.8%
Government payee	1814	22.2%
Factory workers/managers	1485	18.2%
Farmers	313	3.8%
Students	2006	24.6%
Others	1167	14.3%
Family monthly income		
0/1000 RMB	607	7.4%
1001/2000 RMB	994	12.2%
2001/4000 RMB	1995	24.5%
4001/6000 RMB	1698	20.8%
6001/8000 RMB	714	8.8%
8001/10000 RMB	977	12.0%
10001/20000 RMB	620	7.6%
20001/4000000 RMB	216	2.6%
Not sure/unanswered	337	4.1%
Smoked during the last month (yes)	1087	13.3%

Drinking during the last month		
Yes	1088	13.3%
Give up	308	3.8%
Do not drink	6762	82.9%
Body Mass Index		
Underweight	1574	19.3%
Normal	4263	52.3%
Overweight	1264	15.5%
Obese	133	1.6%
Not available	924	11.3%
Infected with COVID-19? (Yes)	57	0.7%
Do you currently live with your partner?		
Yes	4420	54.2%
No	1434	17.6%
I do not have a partner	2304	28.2%
Do you have a health professional family member? (yes)	3001	36.8%
From the area with community infection		
Hubei Province	319	3.9%
Outside Hubei Province with 100+ cases	3400	41.7%
Other	4439	54.4%
Is a family member part of local community efforts against COVID-19	2835	35.1%
Total	8158	100.0%

2. Risk perception, information source, knowledge, attitude, four NPIs and self-isolation

Close to 7% of respondents were aware of the seriousness of the situation on 11 January 2020 when the first COVID-19 related patient death was announced by the Wuhan Health Commission; 39% on 20 January 2020 with the announcement of COVID-19 transmission amongst humans; 29% on 23 January 2020 with the lockdown of Wuhan City; 24% after 24 January 2020 due to the activation of the Level 1 public emergency responding scheme by local governments as well as strict measures and lockdown of neighborhood or villages [11]. Nine respondents (0.1%) did not think it was serious at the time (Figure 2). Overwhelmingly, the majority (99.2%) strongly agreed with the position that the fight against COVID-19 was everyone’s responsibility (Table 2). Close to 97% perceived government websites, APP and the public media as the most authoritative source of information; 90% felt that government websites, APP and the public media were also the most involved source of information; 99.6% of respondents knew why and how to wash hands properly during the COVID-19 outbreak period; 97.2% were aware of the proper procedures when coughing (turning away from people and covering mouth and nose when coughing and washing hands afterwards); 97.8% knew

the right way of practicing social distancing (i.e., keeping social distance more than 1 meter and avoiding close contact with those who had a fever or cough); and 99.9% knew why and how to wear a mask. The overwhelming majority also reported that they translated this knowledge into practice: 96.8% when washing hands; 93.1% when coughing; 87.1% when social distancing; and 97.9% when wearing a mask (Table 2).

Figure 2: When felt the sitatuion was very serious

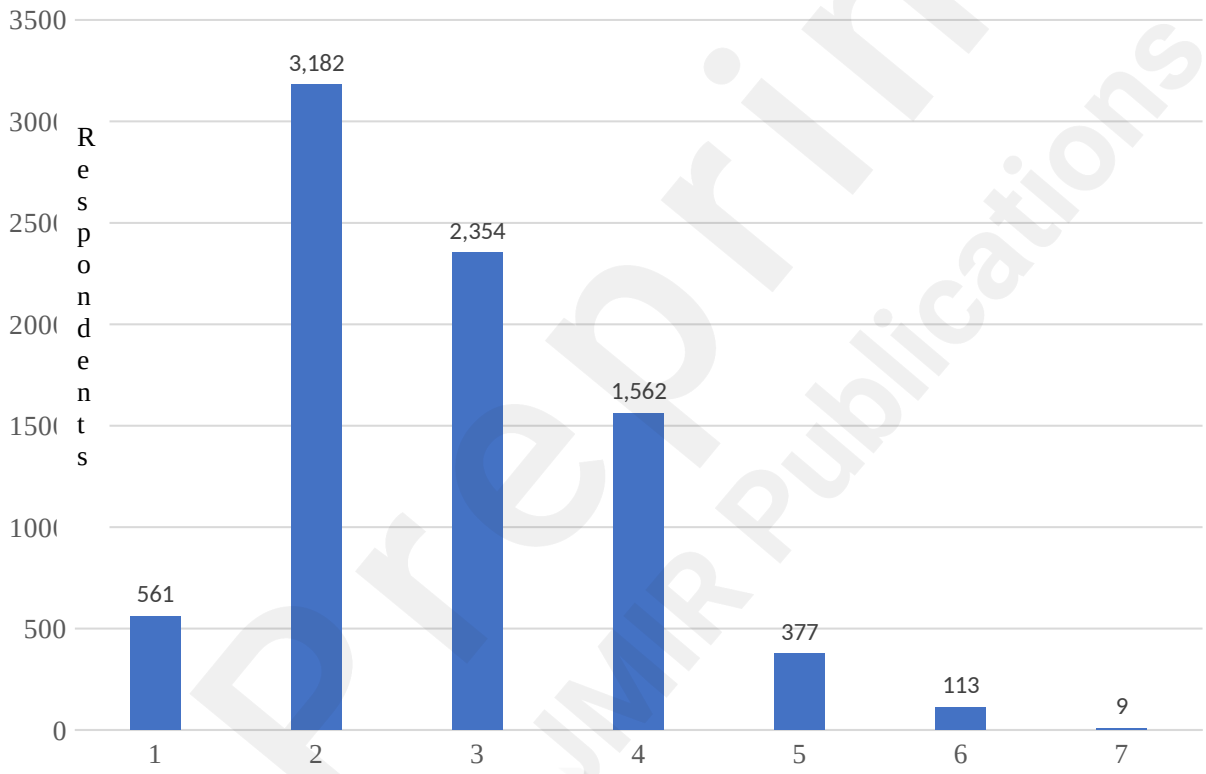


Table 2: Attitude, source of information, knowledge and four NPIs

	N=8158	%
Agree with that the fight with COVID-19 is everyone's job (Yes)	8094	99.2%
Perceived most authoritative source of information		
Government websites/APP/Public media	7902	96.9%
Weibo/Webchat friends	128	1.6%
QQ/webchat groups	64	0.8%
Family/friends	40	0.5%
Other	24	0.3%
Perceived most interested source of information		

Government websites/APP/Public media	7396	90.7%
Weibo/Webchat friends	470	5.8%
QQ/webchat groups	218	2.7%
Family/friends	60	0.7%
Other	14	0.2%
Know why and how to wash hands (Yes)	8129	99.6%
Know the proper habit when coughing (Yes)	7927	97.2%
Know why and how to practice social distancing (Yes)	7975	97.8%
Know why and how to wear a mask in public (yes)	8146	99.9%
Washing hands (Yes)	7895	96.8%
Acting in proper habit when coughing (Yes) *	5997	93.1%
Practicing social distancing (Yes)	7104	87.1%
Wearing a mask when went out (yes)§	5012	97.9%
Repeated use of a mask (yes)§?	5117	99.9%

*: Only 6444 included as 1714 person reported that they did not cough during the last month.
§: Only 5120 respondents of who went out during the period after outbreak included

Our multivariable models found that the knowledge of the relevant NPIs was one of the strongest predictors of that behavior (OR=22.6 for hand washing, OR=4.26 for social distancing, all *Ps* < 0.001, and positive knowledge level associated with a proper coughing habit and mask wearing were 100% and excluded from the models (Appendix 2: eTable 1). The belief that the task of fighting against COVID-19 is everyone's responsibility was positively associated with hand washing (OR=5.59; *P*<0.001), social distancing (OR=3.76; *P*<0.001) and mask wearing (OR=26.89; *P*<0.001). Those who perceived the seriousness of the situation before the lockdown of Wuhan City were more likely to practice hand washing (OR=1.43; 95% CI:1.08 -1.90; *P*=0.014), a proper coughing habit (OR=1.54; 95% CI: 1.24-1.92; *P*<0.001). Those who had a family member involved in the local community efforts against COVID-19 and people from outside the Hubei Province were more likely associated with positive NPIs. In comparison to those who were currently living with a partner, those who did not have partner were less likely to practice hand washing (OR=0.57; 95% CI: 0.35-0.95; *P*=0.032), proper coughing habits (OR=0.59; 95% CI:0.41-0.83; *P*=0.003), but were more likely to practice social distancing (OR=1.64; *P*<0.001). The respondents who have a normal body weight were more likely to practice social distancing (OR=1.21; 95% CI:1.01-1.46; *P*=0.037) than those who were underweight. Non-smokers were more likely to practice social distancing (OR=1.39;

95% CI:1.14-1.71; *P*=0.001) than smokers. Family income, education, occupation, residential area, sex and age groups demonstrated differential impacts on different NPIs (Appendix 2; eTable 1).

Approximately 23% of respondents reported had a Chinese New Year party with invited guests (Appendix 2; eTable 2). The major reasons for the family member who stayed longest at home included: 1) complying with the call from the government (65.6%); 2) self/compulsory isolation (13.6%); 3) fear of the virus (5.7%); 4) the focus on family protection (3.8%); and 5) no mask (3.0%). The main reason for going out were: 1) shopping (40.5%); 2) partaking in a work-related to controlling COVID-19 (32.1%); 3) usual employment (21.4%); 4) going for a walk (2.6%); 5); receiving delivery (0.7%); and 6) socializing/dinner party (0.3%). Over 74% shortened the time to avoid infection when they were out; close to 20% acted in the usual way; and 1% (50) stayed longer than usual, given the restrictions and difficulties to leave home (Appendix 2; eTable 2).

3. Risk association between the COVID-19 infection and hand washing, coughing habits, social distancing and mask wearing

The distribution of the COVID-19 infection across demographic and social economic status variables are presented (Table 3). The bivariate analyses between individual NPIs and the COVID-19 infection showed that there was a significantly increased risk of COVID-19 infection (Table 5) for those who did not wash their hands (2.28% vs 0.65%: RR=3.53; 95% CI: 1.53-8.15; *P*=0.009); who did not practice proper coughing (1.79% vs 0.73%: RR=2.44; 95% CI:1.15-5.15; *P*=0.026); who did not practice social distancing (1.52% vs 0.58%; RR=2.63:95% CI:1.48 - 4.67; *P*=0.002); and who did not wear a mask (7.41% vs 0.6%; RR=12.38:95% CI:5.81-26.36; *P*<0.001). The adjusted ORs were 4.67 (95% CI:1.86-11.74; *P*=0.001) for not washing hands; 2.78 (95% CI:1.22 - 6.33; *P*=0.015) for not practicing proper coughing; 2.13 (95% CI:1.17-3.85; *P*=0.013) for not practicing social distancing and 11.03 (95% CI:4.53-26.84; *P*<0.001) for not wearing a mask (Table 4: Model 1-

Model 4). The model which adjusted all four NPIs plus social demographic variables (Table 4: Model 5;) showed that not wearing a mask was the only significant predictor of infection (OR=7.20; 95% CI:2.24-23.11;*P*<0.001). In comparison between those who were only primary school educated, those with a high school qualification showed they were less likely to be infected (OR=0.12;95%CI:0.05 - 0.31; *P*<0.001). This was similar to those who had professional college qualifications (OR=0.10; 95%CI:0.03-0.29; *P*<0.001) or with university degrees (OR=0.15; 95%CI:0.05-0.46; *P*=0.001; Table 4: Model 6). Non-smokers were less likely to be infected than smokers (OR=0.40; 95%CI: 0.20 – 0.80; *P*=0.01) and those with a monthly family income of 8,001-10,000 RMB were less likely to be infected than those having a monthly family income of less than 1,000 RMB (OR=0.20; 95% CI:0.05-0.88; *P*=0.033) Table 4:Model 6). Consisting with the effective sizes of four NPIs from both bivariable and multivariable analyses, the Area Under the Receiver Operating Characteristics Curve (AUROC) were 0.749, 0.769, 0.749 and 0.825 for hands washing, coughing habits, social distancing and wearing mask, respectively (Table 4: Model 1 – Model 4). The AUROC values demonstrated a fair predictive power of hands washing, coughing habits and social distancing models but good predictive power of mask wearing multivariable model.

Table 3: The rate of COVID-19 infection (0.7%) across social demographic variables.

	n	%	*P*
Age groups			
18-39 years	5017	0.58	0.140
40-59 years	2902	0.86	
>=60 years	239	1.26	

Sex			
Male	3020	1.03	0.008
Female	5138	0.51	
The area that you are currently living			
Rural	2325	0.82	0.461
City	5833	0.65	
Education			
Primary school	130	6.15	<0.001
High school	2040	0.69	
Professional college	2331	0.56	
University/post-graduate	3657	0.60	
Occupation			
Health professionals	1373	0.66	0.174
Government payee	1814	0.77	
Factory workers/managers	1485	0.94	
Farmers	313	1.28	

Students	2006	0.35	
Others	1167	0.77	
Income			
0/1000 RMB	607	1.32	0.196
1001/2000 RMB	994	0.70	
2001/4000 RMB	1995	0.80	
4001/6000 RMB	1698	0.77	
6001/8000 RMB	714	0.56	
8001/10000 RMB	977	0.20	
10001/20000 RMB	620	0.81	
20001/4000000 RMB	216	0.93	
Not sure/unanswered	337	0.00	
Smoked during the last month			
Yes	1087	1.84	<0.001
No	7071	0.52	
Drank alcohol during the last month			

Yes	1088	1.10	0.002
Gave up	308	2.27	
Do not drink	6762	0.56	
Body Mass Index			
Underweight	1574	0.76	0.853
Normal	4263	0.68	
Overweight	1264	0.55	
Obesity	133	0.75	
Not available	924	0.87	
Currently live with your partner?			
Yes	4420	0.81	0.014
No	1434	0.98	
I do not have a partner	2304	0.30	
Family member who is a health professional?			
Yes	3001	0.87	0.170
No	5157	0.60	

From the area with community infection			
Hubei Province	319	0.94	0.596
Outside Hubei province with 100+ cases	3400	0.62	
Other	4439	0.74	
Family member who is part of local community efforts against COVID-19			
Yes	2865	0.87	0.166
No	5293	0.60	
Total	8158	0.70	

Note: *P* values from Fish exact test.

Table 4a: Penalized logistic regression model results for COVID-19 infection and hand washing, coughing habits, social distancing, mask wearing[#] (Continued)

	Infected (M1)		Infected (M2)		Infected (M3)	
Variables	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Age groups						
18-39 years						
40-59 years	0.97	(0.51 - 1.85)	0.88	(0.45 - 1.73)	0.93	(0.49 - 1.78)
>=60 years	1.55	(0.46 - 5.25)	1.68	(0.49 - 5.83)	1.71	(0.51 - 5.75)
Sex (Female vs male)	0.76	(0.39 - 1.47)	0.72	(0.36 - 1.44)	0.76	(0.39 - 1.48)
Living in city (urban vs rural)	0.94	(0.50 - 1.77)	0.81	(0.42 - 1.56)	0.91	(0.48 - 1.71)
Education						
Primary school						
High school	0.13***	(0.05 - 0.33)	0.12***	(0.04 - 0.34)	0.12***	(0.05 - 0.31)
Professional college	0.10***	(0.03 - 0.30)	0.10***	(0.03 - 0.31)	0.10***	(0.03 - 0.29)
University/post-graduate	0.16**	(0.05 - 0.48)	0.14**	(0.04 - 0.46)	0.16**	(0.05 - 0.48)
Occupation						
Health professionals						
Government payee	1.51	(0.63 - 3.67)	1.67	(0.65 - 4.28)	1.54	(0.63 - 3.73)
Factory workers/managers	1.82	(0.66 - 5.00)	2.12	(0.74 - 6.09)	1.87	(0.68 - 5.17)
Farmers	1.02	(0.25 - 4.14)	0.95	(0.21 - 4.39)	0.99	(0.24 - 4.13)
Students	0.97	(0.26 - 3.69)	0.90	(0.22 - 3.70)	1.10	(0.29 - 4.17)
Others	1.63	(0.51 - 5.19)	1.79	(0.52 - 6.09)	1.73	(0.54 - 5.55)
Family monthly income						
0/1000 RMB						
1001/2000 RMB	0.70	(0.25 - 1.96)	0.58	(0.20 - 1.75)	0.61	(0.22 - 1.68)
2001/4000 RMB	0.79	(0.32 - 1.93)	0.69	(0.27 - 1.74)	0.73	(0.30 - 1.77)
4001/6000 RMB	0.68	(0.27 - 1.71)	0.62	(0.24 - 1.62)	0.63	(0.25 - 1.57)
6001/8000 RMB	0.54	(0.16 - 1.83)	0.56	(0.16 - 1.93)	0.50	(0.15 - 1.69)
8001/10000 RMB	0.21*	(0.05 - 0.93)	0.13*	(0.02 - 0.76)	0.20*	(0.05 - 0.88)

10001/20000 RMB	0.67	(0.20 - 2.22)	0.62	(0.19 - 2.07)	0.63	(0.20 - 2.06)
20001/4000000 RMB	0.54	(0.12 - 2.51)	0.53	(0.11 - 2.48)	0.55	(0.12 - 2.45)
Not sure/unanswered	0.15	(0.01 - 2.63)	0.15	(0.01 - 2.62)	0.13	(0.01 - 2.32)
Smoked during the last month (no vs yes)	0.38**	(0.19 - 0.76)	0.38**	(0.18 - 0.77)	0.42*	(0.21 - 0.84)
Drank alcohol during the last month						
Yes						
Gave up	1.96	(0.76 - 5.04)	2.07	(0.79 - 5.44)	1.94	(0.75 - 4.97)
Do not drink	0.88	(0.42 - 1.87)	0.87	(0.40 - 1.89)	0.84	(0.40 - 1.78)
Body Mass Index						
Underweight						
Normal	0.80	(0.41 - 1.59)	0.76	(0.37 - 1.57)	0.80	(0.41 - 1.59)
Overweight	0.49	(0.19 - 1.25)	0.55	(0.21 - 1.43)	0.49	(0.19 - 1.26)
Obese	0.88	(0.16 - 4.94)	1.06	(0.19 - 6.06)	0.94	(0.17 - 5.28)
Not available	1.15	(0.46 - 2.86)	1.17	(0.45 - 3.07)	1.11	(0.45 - 2.78)
Currently live with your partner?						
Yes						
No	1.34	(0.69 - 2.63)	1.36	(0.67 - 2.77)	1.37	(0.70 - 2.69)
I do not have a partner	0.50	(0.19 - 1.34)	0.71	(0.26 - 1.90)	0.55	(0.21 - 1.49)
Family member who is health professional ? (yes vs no)	0.53	(0.26 - 1.08)	0.59	(0.28 - 1.23)	0.50	(0.24 - 1.01)
Living in the area with a community infection						
Hubei Province						
Outside Hubei Province with 100+ cases	0.46	(0.14 - 1.53)	0.46	(0.13 - 1.61)	0.49	(0.14 - 1.65)
Other	0.74	(0.23 - 2.36)	0.82	(0.25 - 2.63)	0.81	(0.25 - 2.62)
Family member who is part of the local community efforts against COVID-19 (no vs yes)	0.70	(0.37 - 1.30)	0.64	(0.34 - 1.22)	0.76	(0.41 - 1.42)
Hand washing (no vs yes)	4.67**	(1.86 - 11.74)				
Proper coughing habit (no vs yes)			2.78*	(1.22 - 6.33)		
Social distancing (no vs yes)					2.13*	(1.17 - 3.85)
Mask wearing (no vs yes)						
Constant	0.67	(0.09 - 4.81)	0.90	(0.11 - 6.99)	0.60	(0.08 - 4.42)
Observations	8,158		6,444		8,158	
AUROC	0.749		0.769		0.749	

#M1-M5: 5 models adjusting for social demographic variables plus hand washing, coughing habits, social distancing, mask wearing and all four NPIs together, respectively; M6: adjuring for social demographic variables only.
§: AUROC: The Area Under the Receiver Operating Characteristic Curve
*** P<0.001, ** P<0.01, * P<0.05
Note: For each model, the convergency of penalized maximum likelihood function was monitored, and coefficients and their 95% CIs were examined. Each model converged normally in a short period and no irregularity of coefficients and standard errors was identified.

Table 4b. Penalized logistic regression model results for COVID-19 infection and hand washing, coughing habits, social distancing, mask wearing[#]

	Infected (M4)		Infected (M5)		Infected(M6)	
Variables	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Age groups						
18-39 years						
40-59 years	1.07	(0.47 - 2.42)	1.17	(0.49 - 2.81)	0.95	(0.50 - 1.81)
>=60 years	3.16	(0.82 - 12.11)	3.79	(0.96 - 14.94)	1.68	(0.50 - 5.71)
Sex (female vs male)	0.65	(0.29 - 1.49)	0.69	(0.29 - 1.66)	0.73	(0.38 - 1.42)
Living in city (urban vs rural)	0.85	(0.37 - 1.95)	0.75	(0.32 - 1.77)	0.89	(0.47 - 1.68)
Education						
Primary school						
High school	0.09***	(0.03 - 0.30)	0.11**	(0.03 - 0.43)	0.12***	(0.05 - 0.31)
Professional college	0.09***	(0.03 - 0.34)	0.11**	(0.03 - 0.47)	0.10***	(0.03 - 0.29)
University/post-graduate	0.08***	(0.02 - 0.33)	0.10**	(0.02 - 0.47)	0.15***	(0.05 - 0.46)
Occupation						
Health professionals						
Government payee	1.74	(0.60 - 5.06)	1.59	(0.52 - 4.85)	1.57	(0.65 - 3.81)

Factory workers/managers	1.97	(0.56 - 6.89)	1.80	(0.49 - 6.55)	1.95	(0.71 - 5.33)
Farmers	1.35	(0.25 - 7.27)	0.76	(0.12 - 4.97)	1.08	(0.26 - 4.43)
Students	1.00	(0.19 - 5.36)	0.69	(0.12 - 4.03)	1.18	(0.31 - 4.43)
Others	2.02	(0.49 - 8.27)	2.17	(0.52 - 9.04)	1.72	(0.54 - 5.51)
Family monthly income						
0/1000 RMB						
1001/2000 RMB	0.42	(0.11 - 1.57)	0.58	(0.14 - 2.38)	0.62	(0.23 - 1.72)
2001/4000 RMB	0.77	(0.26 - 2.28)	0.90	(0.28 - 2.92)	0.73	(0.30 - 1.78)
4001/6000 RMB	0.47	(0.14 - 1.52)	0.64	(0.18 - 2.25)	0.63	(0.25 - 1.58)
6001/8000 RMB	0.56	(0.13 - 2.37)	0.73	(0.17 - 3.25)	0.50	(0.15 - 1.68)
8001/10000 RMB	0.31	(0.06 - 1.49)	0.24	(0.03 - 1.62)	0.20*	(0.05 - 0.88)
10001/20000 RMB	0.43	(0.10 - 1.87)	0.53	(0.11 - 2.49)	0.62	(0.19 - 2.03)
20001/4000000 RMB	0.24	(0.02 - 2.61)	0.21	(0.01 - 3.85)	0.60	(0.14 - 2.64)
Not sure/unanswered	0.11	(0.00 - 2.75)	0.26	(0.01 - 4.97)	0.13	(0.01 - 2.36)
Smoked during the last month (no vs yes)	0.67	(0.29 - 1.58)	0.65	(0.27 - 1.57)	0.40**	(0.20 - 0.80)
Drank alcohol during the last month						
Yes						
Gave up	1.29	(0.43 - 3.87)	1.34	(0.43 - 4.20)	2.00	(0.78 - 5.10)
Do not drink	0.48	(0.20 - 1.13)	0.47	(0.19 - 1.15)	0.85	(0.40 - 1.80)
Body Mass Index						
Underweight						
Normal	0.56	(0.25 - 1.25)	0.57	(0.24 - 1.33)	0.79	(0.40 - 1.57)
Overweight	0.26*	(0.07 - 0.90)	0.28*	(0.08 - 0.99)	0.48	(0.19 - 1.25)
Obese	0.31	(0.02 - 5.81)	0.38	(0.02 - 7.45)	0.88	(0.16 - 4.97)
Not available	1.25	(0.46 - 3.44)	1.17	(0.40 - 3.46)	1.13	(0.45 - 2.82)
Currently living with a partner?						
Yes						
No	1.62	(0.69 - 3.82)	1.28	(0.50 - 3.26)	1.38	(0.70 - 2.69)
I don't have a partner	0.98	(0.30 - 3.20)	1.19	(0.36 - 3.91)	0.53	(0.20 - 1.41)
Family member who is a health professional? (yes vs no)	0.51	(0.22 - 1.19)	0.61	(0.25 - 1.48)	0.50	(0.24 - 1.01)
Living in an area with community infection						
Hubei Province						
Outside Hubei Province with 100+ cases	0.24*	(0.06 - 0.95)	0.25	(0.06 - 1.09)	0.45	(0.13 - 1.51)
Other	0.68	(0.19 - 2.50)	0.74	(0.20 - 2.81)	0.78	(0.25 - 2.47)
Family member who is part of the local community efforts against COVID-19 (no vs yes)	0.51	(0.24 - 1.09)	0.46	(0.21 - 1.04)	0.74	(0.40 - 1.37)
Hand washing (no vs yes)			1.82	(0.40 - 8.32)		
Proper coughing habit (no vs yes)			1.88	(0.60 - 5.94)		
Social distancing (no vs yes)			1.07	(0.46 - 2.46)		
Mask wearing (no vs yes)	11.03***	(4.53 - 26.84)	7.20***	(2.24 - 23.11)		
Constant	2.04	(0.19 - 21.47)	1.64	(0.13 - 20.42)	0.78	(0.11 - 5.62)
Observations	5,120		4,154		8,158	
AUROC§	0.825		0.823		0.748	

#M1-M5: 5 models adjusting for social demographic variables plus hand washing, coughing habits, social distancing, mask wearing and all four NPIs together, respectively; M6: adjuring for social demographic variables only

§: AUROC: The Area Under the Receiver Operating Characteristic Curve

*** P<0.001, ** P<0.01, * P<0.05

Note: For each model, the convergency of penalized maximum likelihood function was monitored, and coefficients and their 95%CIs were examined. Each model converged normally in a short time and no irregularity of coefficients and standard errors was identified.

Table 5: The association between COVID-19 infection and four NPIs

Risk of COVID-19 infection (57/8158: 0.70%)			
Risk	Risk Difference(95%CI)	Risk Ratio (RR)	*P*
Washing hands (n=8158)			

No	(6/263) 2.28%	1.63% (-0.18% - 3.45%)	3.53(1.53 - 8.15)	0.009
Yes	(51/7895) 0.65%			
Acting properly when coughing (n=6444)				
No	(8/447) 1.79%	1.06% (-0.19% - 2.3%)	2.44(1.15 - 5.15)	0.026
Yes	(44/5997) 0.73%			
Practicing social distancing (n=8158)				
No	(16/1054)1.52%	0.94% (0.18% - 1.7%)	2.63(1.48 - 4.67)	0.002
Yes	(41/7104) 0.58%			
Wearing a mask outdoors (n=5120)				
No	(8/108) 7.41%	6.81% (1.87% - 11.75%)	12.38(5.81 - 26.36)	<0.001
Yes	(30/5012) 0.60%			

Note: *P* values from Fisher exact test.

4. Potential risk compensating effects amongst four NPIs against COVID-19 infection

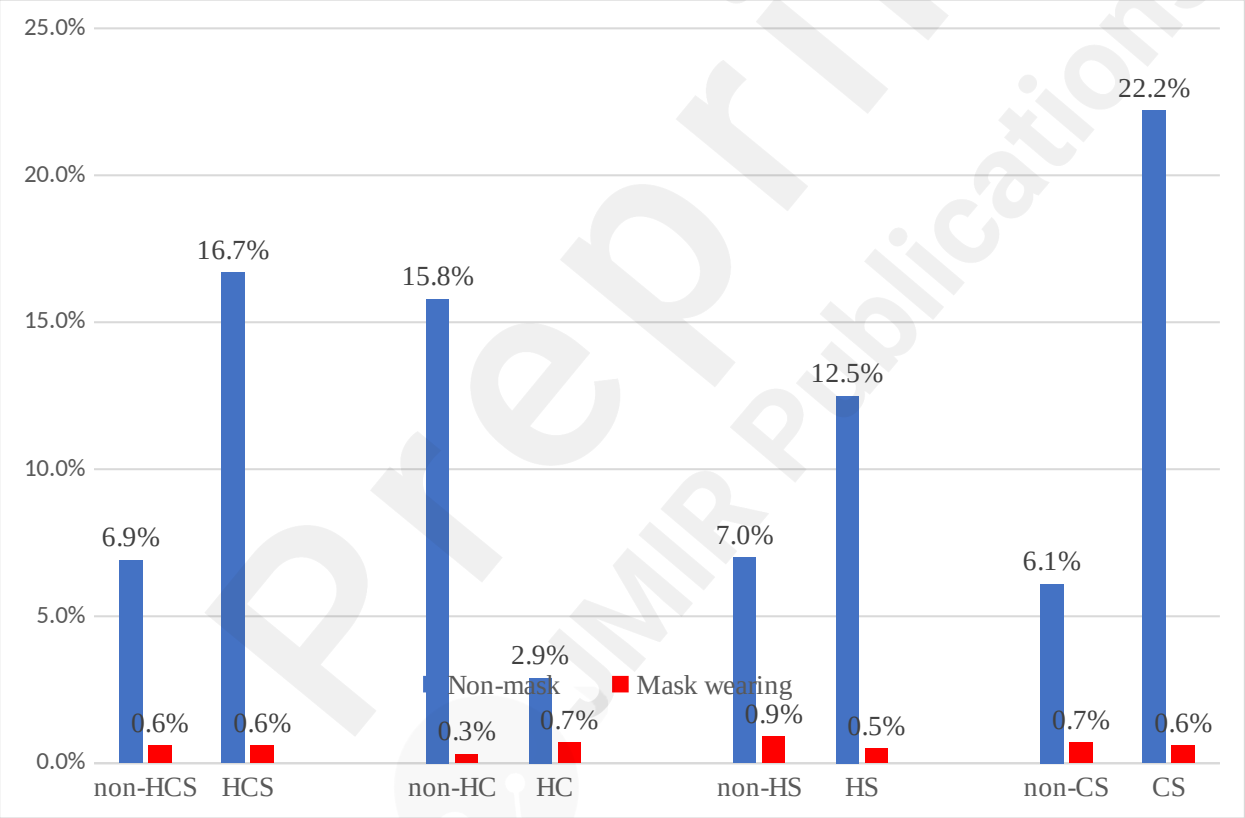
The pairwise distributions of COVID-19 infection rate among four NPIs are presented (Table 6). Wearing mask (versus not) was associated with a significantly reduced risk of COVID-19 infection amongst those who practiced hand washing (0.6% vs 5.3%; RR=0.11; *P*<0.001), proper coughing (0.7% vs 3.9%; RR=0.18; *P*=0.019) and social distancing (0.5% vs 16.7%; RR=0.03; *P*=0.002). Hand washing showed a trend towards a further reduced risk of infection for those who did not practice social distancing (RR=0.25; *P*=0.053). Among those who did not practice social distancing, those who had proper coughing habits were associated with a reduced risk of infection compared to those who did not have proper coughing habits (1.3% vs 4.4%; RR=0.29; *P*=0.048). The added potential protection effect of mask wearing on different combinations of the other three NPIs are presented in Figure 3. For those who did practice all three NPIs (i.e., hand washing (H), proper coughing (C), social distancing (S): HCS), wearing a mask was associated with a significantly reduced risk of infection compared to those who did not (0.6% vs 16.7%;*P*=0.035). Similarly, for those who did not practice all other three NPIs, wearing a mask was also associated with a significantly reduced risk of infection compared to not wearing a mask (Figure 3).

Table 6: The COVID-19 infection rates (%) and potential pairwise risk compensating effect among four NPIs with risk ratio (RR) and *P* values from exact tests

		Mask wearing					
		no		yes		RR (95%CI)	*P*
		N	%	N	%		
Hand washing	No	13	23.1	147	.7	0.03(0.003-0.26)	0.002
	Yes	95	5.3	4865	.6	0.11 (0.04-0.29)	<0.001

Proper coughing	No	11	36.4	318	.6	0.02(0.004-0.08)	<0.001
	Yes	76	3.9	3749	.7	0.18 (0.05-0.57)	0.019
Social distancing	No	96	6.3	958	1.0	0.17 (0.06-0.45)	0.002
	Yes	12	16.7	4054	.5	0.03 (0.01-0.11)	0.002
		Hand washing					
Proper coughing	No	74	4.1	373	1.3	0.33 (0.08-1.35)	0.131
	Yes	118	1.7	5879	.7	0.42 (0.10-1.72)	0.214
Social distancing	No	58	5.2	996	1.3	0.25 (0.73-0.86)	0.053
	Yes	205	1.5	6899	.6	0.38 (0.12-1.21)	0.114
		Proper coughing					
Social distancing	No	90	4.4	776	1.3	0.29(0.09-0.91)	0.048
	Yes	357	1.1	5221	.7	0.58 (0.21-1.63)	0.304

Figure 3: The COVID-19 infection rates between mask wearing and the combinations of the other three NPIs: hand washing (H), proper coughing habit (C) and social distancing (S) (*P* values from Fisher exact test).



Discussion

To the best of our knowledge, our study is the first comprehensive report on the COVID-19 infection rate, perceived risk, knowledge, attitude, four NPIs as well as the self-isolation of a nation-wide adult

sample amidst the late period of the COVID-19 epidemic in China. We found that most respondents were aware of the seriousness of the outbreak at different time periods and believed that it was everyone's responsibility to fight the spread of COVID-19. The positive attitude, earlier risk perception and relevant knowledge were amongst the strongest predictors of hand washing, proper coughing habits, social distancing and mask wearing. Different social demographic factors also contributed to different NPIs. Those who only had a primary school education, with little family income, and being a smoker were associated with the increased risk of COVID-19 infection. Mask wearing, among the four practices, was the most important protection factor against the COVID-19 infection with an added preventive effect amongst those who practiced all or part of the other three NPIs.

Our findings of high levels of knowledge amongst the Chinese public were consistent with the results of a previous study [12]. However, the previous online survey study was conducted at a much earlier stage (i.e., 27 January to 1 February, 2020) with a smaller sample and over half of the respondents were from the Hubei Province which did not include the knowledge and behaviors of hand washing, proper coughing habit, social distancing and self-isolation (but with mask wearing included). The widespread use of mobile phones, the internet, social media APP such as Wechat (with an estimated 1.1 billion registered accounts in China in 2019) [13] have significantly increased the speed and scope of information transmission in China and may be instrumental in the dissemination of COVID-19 related knowledge and information. This was also helped by the fact that over 90% of respondents believed that the government websites, public media and APP were the most authoritative and involved sources of information for COVID-19. Our results suggested that respondents had an extremely positive attitude that fighting against COVID-19 was everyone's responsibility and its association with positive NPIs highlighted the success of a nation-wide campaign in instilling the concept that everyone can, and should, make necessary contributions

towards the fight against COVID-19.

Our study's finding that the early perceived seriousness of the situation was a strong predicting factor for the use of NPIs reinforces the importance of transparency and timely dissemination of critical information regarding the COVID-19 pandemic. Our study showed that around 22% of respondents had a party during Chinese New Year (24-25 January) which is an important Chinese tradition. This period was immediately after the lockdown of Wuhan City (23 January) where there was confusion for those who lived outside the Hubei Province where there was no social distancing and self-isolation in place at the time. Such gatherings could have been avoided if the public had been equipped with real-time knowledge of the danger and seriousness of the situation. Evidence also supported the concept that the early swift NPIs by governments and the education of the public regarding the seriousness of the situation were critical in slowing the spread and flattening the curve [14]. Our study demonstrated that family influences (particularly those with health professionals and with someone being part of a community team fighting against COVID-19) could have a significant positive impact on individual's behaviors. Respondents with various demographic characteristics (such as age groups, sex, marital status, education, occupation, and smoking) had exhibited different NPIs. These findings may provide further opportunities for developing tailored health education campaigns and health policy interventions on segments of the population in order to maximize the effects of the NPIs. For example, specific policies and education could target smokers, the younger population to encourage certain behaviors (such as proper coughing habit) and the older population on other behaviors (such as self-isolation, social distancing and mask wearing).

The reported COVID-19 infection rate (i.e., 0.73%) in our study is higher than then China national infection rate on 5 March 2020 (i.e, 0.0056%) that reflected the fact that disproportional sample were from higher risk Hubei province. Our study found almost universal acceptance of the importance of

mask wearing and a very high proportion (97.9%) wore a mask in public after the outbreak. Our study found that mask wearing, amongst the four personal NPIs, was the most important protective measure against the COVID-19 infection. This may have policy implications. The Chinese public accepted the concept of wearing a mask possibly due to factors such as the previous SARS epidemic experience [15], the coordinated nation-wide education campaign, the earlier recognition of the existence of asymptomatic virus carriers, the strict measures in reinforcing such a role (e.g., in shopping centers, public transportation, etc.), the coordinated efforts in rationing the supply of masks to families over the shortage period. The necessity in wearing a mask in public may be controversial in different countries and agencies [16-20] despite the positive evidence in favoring wearing a mask in a simulated environment [21 22]. It is likely to be an evolving policy option depending on several factors, including the availability of masks and fair distribution channels amongst society. Our findings that wearing a mask had an added preventive effect, even among those who did practice all or part of other three NPIs, provided contradictive evidence regarding the opinion that the other three NPIs alone were sufficient in preventing the COVID-19 infection. It also did not support the opinion that wearing a mask could even increase the risk of infection through more facial contact. For those countries still in the grip of the pandemic or who are considering re-opening their economy, a policy of encouraging or requiring the public to wear a mask may have a positive impact especially in highly populated areas or in settings where other NPIs are very difficult to implement (such as in a bus, airplane or shopping center). During the study period, there were still 3% of respondents who reported that ‘no mask’ was the main reason for stopping them from going out and most respondents had repeatedly used the same mask. Given the likelihood of a surge in demand for masks during an outbreak, public health agencies and related authorities may also need to provide practical and evidence-based guidance on when and how to appropriately reuse a mask. China contributed over half of the global mask manufacturing output before the outbreak but still faced the shortage of masks over the epidemic period [23]. It is important for governments and international agencies to

rethink the adequacy of, and better approaches towards, their strategic stockpiles of masks and other personal protection equipment (PPE) for the current and future pandemics.

Our study has several strengths. First, it was the largest study of its kind to cover the most critical period of the COVID-19 outbreak in China. Second, our study design and analysis was driven by policy needs and included many factors such as demographics, social economic status, family contextual factors, risk perception, knowledge, attitude, and personal practices. Third, the adoption of the internet survey methodology enabled us to complete our study in a critical period and in a cost-effective manner. Our study also has several limitations. First, our study sample had disproportionately more female, well-educated and less smokers, reflecting a typically young and healthy cohort in similar surveys. Thus, the frequencies of desirable knowledge levels and health behaviors may be over-estimated while less desirable outcomes (such as lower family monthly income) may be under-estimated. However, the modelling results may be less susceptible to these potential biases. Second, our study results were from a particular period of the outbreak and most of the respondents were from outside Hubei Province. The generalization of the results to other settings and countries may be limited. Third, our study was a cross-sectional population survey and the association found between the predictors and outcomes should be interpreted with caution and further intervention studies are needed in confirming our findings. Fourth, despite the relatively large sample size, the total cases of COVID-19 infections were still small so that the relationship between NPIs and the Covid-19 infection should be confirmed by other larger epidemiological studies. Fifth, the potential risk compensating effects of wearing a mask against other NPIs should be considered as being of a hypothesis-generating nature given the potential limitations outlined above. Sixth, all the information collected in the study was self-reported that could suffer from potential biases. Common to any observational studies with multiple outcomes and modelled with different effective sample sizes, the interpretations and generalization of the results should be strictly limited to the same

setting and beware of multiple tests risks.

In summary, our study found a high level of risk perception, positive attitude, desirable knowledge and practices in hand washing, proper coughing habit, social distancing and mask wearing amongst a large cohort of Chinese adults. Our study also found that the relevant knowledge, risk perception and attitude were amongst the strongest predictors of the four NPIs. Wearing a mask, among the four NPIs, was the predominating protective measure against the COVID-19 infection with an added preventive effect amongst those who practiced all or part of the other three NPIs. Our findings of many different predictors on different personal NPIs may also provide the possibility for further tailored health policy interventions. The study also emphasizes the importance, at an international level, of sharing information in a collaborative way in order to learn from everyone's experiences about what interventions worked well and what were the impact of issues that may have resulted in poor outcomes such as delayed and misinformed actions.

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Conflict of Interests

All authors declaimed no conflict of interests.

Authors' contributions

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HX, YG, ZXL conceived and designed the study. HX, YG, DKZ, BW, XZ, CX, CLL, ZT, MC, and MJL participated in the acquisition of data. JC, HX, XZ conceptualised the theoretical and analytical framework and conducted data management and statistical analysis. ZXL, YYH provided advice on the methodology. JC, HX, YG, XZ conducted the literature review and HX, YG, and XZ provided the first draft of the manuscript. JC produced all the final tables and figures as well as the final draft for review. ZXL, YYH and other authors revised the manuscript. All authors read and approved the final manuscript. JC (jackchen@unsw.edu.au) is the guarantor of this work and has full access to all the data in the study and takes responsibility for its integrity and the accuracy of the data analysis.

Abbreviations:

BMI: Body Mass Index

CI: Confidence Intervals

COVID-19: Coronavirus disease of 2019

NIPs: non-pharmaceutical interventions

OR: Odds ratio

RR: Risk ratio

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Supplementary Files

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Multimedia Appendixes

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