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ORIGINAL RESEARCH

# Quantifying the Adverse Effects of Long COVID on Individuals' Health After Infection: A Propensity Score Matching Design Study

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**Objective:** To evaluate the prevalence and influencing factors of long COVID, and measure the difference in health status between long COVID and non-long COVID cases.

**Methods:** A cross-sectional survey was conducted from February 1 to 8, 2023, using a stratified random sampling method in four regions (eastern [Changzhou], central [Zhengzhou], western [Xining] and northeastern [Mudanjiang]) of China. The survey collected COVID-19 patients' socio-demographic characteristics and lifestyles information. The scores of lifestyles and health status range from 5 to 21 and 0 to 100 points, respectively. The criteria of "persistent health problems after 4 weeks of COVID-19 infection" issued by the US Centers for Disease Control and Prevention was used to assess long COVID. Multiple linear regression was used to analyze the influencing factors of the health. The bootstrap method was used to analyze the lifestyles' mediating effect. Propensity score matching (PSM) was used to evaluate the net difference in health scores between long COVID and non-long COVID cases.

**Results:** The study included 3165 COVID-19 patients, with 308 (9.73%) long COVID cases. The health score of the long COVID cases (74.79) was lower than that of the non-long COVID cases (81.06). After adjusting for potential confounding variables, we found that never focused on mental decompression was a common risk factor for the health of both groups. Lifestyles was the mediating factor on individuals' health. After PSM, the non-long COVID cases' health scores remained higher than that of long COVID cases.

**Conclusion:** The proportion of long COVID cases was low, but they were worse off in health. Given the positive moderating effect of healthy lifestyles on improving the health of long COVID cases, healthy lifestyles including mental decompression should be considered as the core strategy of primary prevention when the epidemic of COVID-19 is still at a low level.

**Keywords:** long COVID, lifestyles, self-reported health status, propensity score matching, effect of mediation

## Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a novel virus, has caused a worldwide pandemic of coronavirus disease 2019 (COVID-19). Although the World Health Organization has declared that "COVID-19 no longer constitutes a Public health Emergency of International concern",[1] but this does not mean that COVID-19 infection is over. COVID-19 is still circulating at a low level, and data suggest that by April 2023, approximately 764 million people worldwide had contracted the COVID-19 virus.[2] A large proportion of infected people can return to their pre-infection life after recovery.[3] However, one study has shown that COVID-19 infection can cause sequelae in the immune system, blood system, lung system, cardiovascular system, gastrointestinal system, musculoskeletal system, nervous system, and

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other aspects.[4] These sequelae may persist after infection and may recur after cure.[5] This disease, which manifests as persistent symptoms that affect some people after infection, is known as long COVID and affects people's health.[6]

Currently, there is no universally known definition of long COVID. In this study, the definition of long COVID as defined by the Centers for Disease Control and Prevention of the United States of America was adopted: the condition in which an individual has persistent symptoms or health problems for at least 4 weeks (28 days) after COVID-19 infection.[7] Persistent symptoms include a range of physical and mental (psychological) symptoms,[8] including fatigue,[9] headache, joint pain,[10] respiratory symptoms,[11] cognitive impairment and impaired mental health.[12] The persistent effects of these symptoms can lead to poorer health and reduced quality of life.[13] One study shows that at least 65 million people are infected with long COVID-19 worldwide,[14] but due to lack of surveillance and reporting, the actual number of infected people may be much higher than reported. Previous studies have revealed risk factors for long COVID-19, such as being female,[15,16] the number of symptoms during the infection,[17] education level, smoking,[18,19] sleep,[20,21] and psychological factors.[22]

In February 2023, China announced the implementation of "Class B epidemic and B management" control measures for COVID-19 to reduce the negative impact of large-scale lockdown.[23] This policy indicates that the Chinese government will no longer adopt strict quarantine measures for COVID-19 infected people and close contacts, no longer divide high-risk areas and low-risk areas, and the population in each area can move freely. As a result of this policy, the risk of COVID-19 infection has increased nationwide, and acute cases have been treated in a timely and effective manner. However, the health status of long COVID cases also requires urgent attention. The purpose of this study is to explore the health status and influencing factors of individuals with and without long COVID after the social distancing strategy has ended in China, and to explore the effects of long COVID infection on the health of individuals and the regulatory effect of lifestyle to develop targeted healthy lifestyle guidance and policy recommendations to improve the health status of long COVID cases.

# Methods

## Procedures and Participants

From February 1 to 8, 2023, a cross-sectional study was conducted in the eastern (Changzhou), central (Zhengzhou), western (Xining) and northeastern (Mudanjiang) areas of China mainland using a stratified random sampling method (see Figure S1). Within each city, more than two rural areas and two urban areas were randomly selected. A cross-sectional online survey was conducted among adults aged 18 years and above in each household to obtain a sample of 5780 eligible participants.

In this study, a total of 3165 patients infected with COVID-19 were enrolled. The sample exclusion criteria were as follows: minors aged less than 18 years, participants with incomplete information, were not infected with COVID-19, and individuals who were not residents of China mainland.

We performed 1:1 nearest neighbor matching between long COVID cases and non-long COVID cases, and a total of 281 pairs of samples were matched. The participant flow chart is shown in Figure 1.

## Ethics Approval

Participants were informed of the benefits and risks of participating in this study, and they provided informed consent. All data were used merely for research purposes. This study was approved by the Life Science Ethics Review Committee of Zhengzhou University (2021–01-12-05).

## Assessments

In the questionnaire, participants were asked about the post-COVID-19 symptoms they experienced after testing negative for COVID-19. Additionally, they were asked to indicate the duration of these symptoms in terms of the number of days. Participants who self-reported symptoms lasting for more than 4 weeks (28 days) were categorized as long COVID cases based on the measurement criteria used in the study. The health status of participants was assessed using a questionnaire that asked them to rate their current health status on a scale from 0 to 100. Higher scores on the scale indicated a better health status.

We used 13 covariates (sociodemographic factors and health factors), including gender (male, female), age (18–29, 30–39, 40–49, 50–59, ≥60), marital status (married, other), education level (high school or less, bachelor's degree or more), religious affiliation (atheist, others), ethnic (Han, Minority), annual household income (CNY) (<20,000, 20,000–49,999,

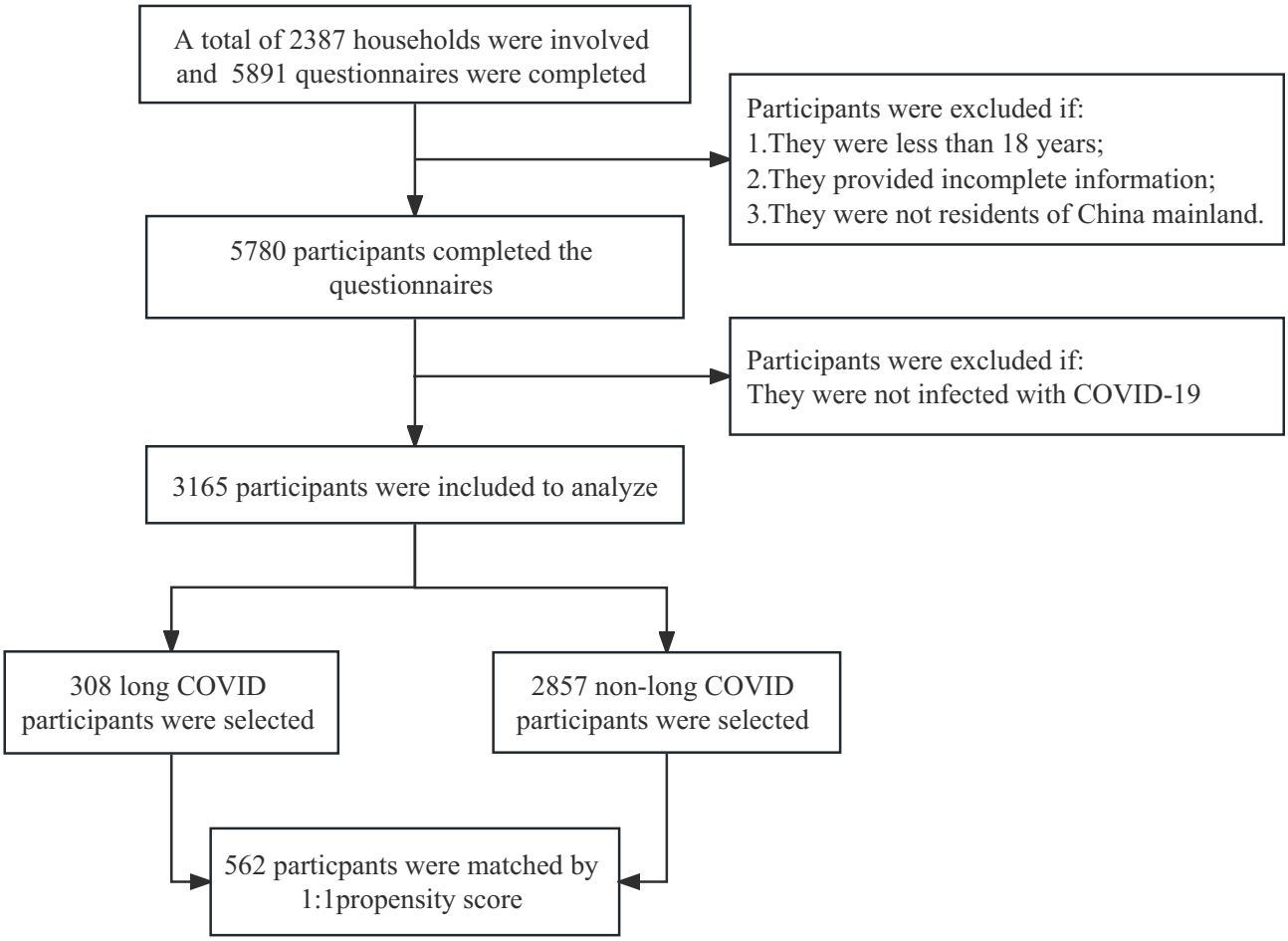


**Figure 1** The flowchart of participants selection of this study.

50,000–99,999, 100,000–199,999, ≥200,000), BMI (<18.50, 18.50–24.99, 25.00–29.99, ≥30.00), smoking (smoking, quit, never), drinking (drinking, quit, never), wearing masks (always, often, sometimes, seldom, never), sufficient sleeping (always, often, sometimes, seldom, never), and mental decompression (always, often, sometimes, seldom, never).

To verify the mediating effect of smoking, drinking, wearing masks, sufficient sleeping, and mental decompression on the health status of individuals affected by long COVID, we assigned scores to each aspect. Smoking status was scored as 1 point for current smokers, 2 points for those who had quit smoking, and 3 points for individuals who had never smoked. Similarly, drinking status was scored as 1 point for current drinkers, 2 points for ex-drinkers, and 3 points for those who had never consumed alcohol. The frequency of wearing masks, sufficient sleeping, and mental decompression were evaluated and assigned scores based on the following scale: always = 5 points, often = 4 points, sometimes = 3 points, seldom = 2 points, and never = 1 point. The overall scores for these factors ranged from 5 to 21, reflecting the cumulative assessment of participants' behaviors in these areas.

## Statistical Analysis

The rank-sum test of two independent samples and the Kruskal–Wallis test were used to analyze the differences in health status scores between the long COVID cases and non-long COVID cases. The frequencies and proportions of categorical variables were calculated, along with their corresponding health status scores while continuous variables were categorized into quartiles, and the frequencies and proportions within each quartile were reported along with the respective health status scores. The factors influencing the health status score were analyzed by using linear regression models. A bias-corrected non-parametric percentile bootstrap method was used to verify the mediating effect of lifestyle on the

impact of long COVID on the health status of patients. To minimize the potential influence of confounding factors, propensity score matching was employed. Covariate selection was carried out using probit regression, and the propensity score was calculated through probit regression as well. Subsequently, 1:1 nearest neighbor matching was conducted between the long COVID and non-long COVID populations among the 3,165 individuals, ensuring a balanced comparison between the two groups while addressing potential biases. All analyses were performed by using STATA17.0 and SPSS27.0 statistical software, and $P<0.05$ was considered statistically significant.

# Results

## Characteristics, Lifestyles and Health Status Scores of Long COVID and Non-Long COVID Cases

The basic characteristics, lifestyles, and health status scores of the participants are presented in Table 1. A total of 3165 COVID-19 patients were included in this study, of which 308 (9.73%, 95% CI: 8.70~10.76) were long COVID cases and 2857 (90.27%, 95% CI: 89.24~91.30) were non-long COVID cases. The overall health status score of COVID-19 patients was 80.45 (95% CI: 79.91~80.99) The health status score of long COVID cases was 74.79 (95% CI: 72.75~76.82), which was lower than that of non-long COVID cases 81.06 (95% CI: 80.50~81.61).

The findings show that among long-COVID cases, lower education level (68.33, 95% CI: 62.87~73.8), higher annual income level of 50,000–99,999 yuan (68.46, 95% CI: 63.73~73.19), never felt sufficient sleep (60.50, 95% CI: 20.16~100.84) and those who never paid attention to mental decompression (61.05, 95% CI:51.66~70.44) had the lowest health status score. Among non-long COVID cases, the elderly (76.73, 95% CI: 75.45~78.01), lower education level (79.69, 95% CI: 78.78~80.6), non-married (80.71, 95% CI: 80.12~81.29), those who with religious belief (80.56, 95% CI: 76.10~85.02) had the lowest health status score. Those who never drank alcohol (81.52, 95% CI: 80.86~82.19) and those who always wore masks (82.97, 95% CI: 82.03~83.91) had the highest health status scores. In addition, people who always slept enough (81.00, 95% CI: 76.55~85.45; 85.01, 95% CI: 83.85~86.16) and those who always had mental decompression (92.60, 95% CI: 86.99~98.21; 86.95, 95% CI: 85.23~88.68) had higher health status scores.

## Influencing Factors of Health Status of Long COVID and Non-Long COVID Cases

After accounting for confounding factors, the results of the linear regression model revealed that religious belief, annual household income, education level, wearing masks, smoking, drinking, and mental decompression (all $P<0.05$) were significantly associated with the health status of long COVID cases, and the influencing factors of the health status score of non-long COVID cases were age, religious belief, BMI, annual household income, sufficient sleep and mental decompression (all $P<0.05$), as shown in Figure 2 (see Table S1).

Atheism was associated with a higher health status score among long COVID cases ($\beta$=11.69, 95% CI: 0.25~23.13), while those with a bachelor's degree or higher had a better health status score ($\beta$=7.44, 95% CI: 1.14~13.74). People who seldom used masks had lower health scores ($\beta$=7.33, 95% CI: −14.29~-0.37). Among non-long COVID cases, the health status score of the elderly (≥60 years old) was lower ($\beta$=−10.30 95% CI: −12.91~-7.70), and the health status score of atheism was higher ($\beta$=4.12, 95% CI: 1.09~7.14). People with normal BMI (18.5–25.0) had higher health status score ($\beta$=4.03, 95% CI: 0.9~7.15), and those who never felt sufficient sleep had lower health status score ($\beta$=−15.8, 95% CI: −26.72~-4.88).

Moreover, among long COVID cases, those who had quit smoking ($\beta$=10.92, 95% CI%: 4.23~17.62) and those who had never smoked ($\beta$=12.83, 95% CI: 3.83~21.83) had higher health status scores than smokers. Ex-drinkers ($\beta$=−14.28, 95% CI: −22.68~-5.88) and never-drinkers ($\beta$=−5.56, 95% CI: −11.01~-0.10) had lower health status scores than drinkers, however, there was no statistically significant difference in non-long COVID cases (all $P>0.05$). In both groups, those who never paid attention to mental decompression had the lowest health status score ($\beta$=−25.40, 95% CI: −38.82~-11.98; $\beta$=−4.86, 95% CI: −7.51~-2.21), which represented the worst health status.

## Mediating Effect Analysis of Lifestyle Scores

As shown in Figure 3, long COVID significantly positively predicted health status scores (c=6.2734, $P<0.001$) and negatively predicted lifestyle scores (a=−0.3542, $P<0.05$). When both long COVID and lifestyle were considered in the

**Table 1** The Characteristics, Lifestyles and Health Status Scores of the Study Participants

| Variables | Total % | Health Status Scores (95% CI) | *P* value[a] | Long COVID | | | Non-long COVID | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | (N=308) % | Health Status Scores (95% CI) | *P* value[b] | (N=2857) % | Health Status Scores (95% CI) | *P* value[c] |
| **Total** | 3165 (100) | 80.45 (79.91~80.99) | | 308 (9.73) | 74.79 (72.75~76.82) | | 2857 (90.27) | 81.06 (80.50~81.61) | |
| **Sex** | | | 0.413 | | | 0.697 | | | 0.300 |
| Male | 1484 (46.89) | 80.30 (79.51~81.08) | | 123 (39.94) | 74.19 (70.94~77.43) | | 1361 (47.64) | 80.85 (80.05~81.65) | |
| Female | 1681 (53.11) | 80.58 (79.83~81.33) | | 185 (60.06) | 75.18 (72.57~77.8) | | 1496 (52.36) | 81.25 (80.47~82.02) | |
| **Age** | | | **0.0001** | | | 0.253 | | | **0.0001** |
| 18–29 | 357 (11.28) | 85.29 (83.67~86.92) | | 19 (6.17) | 77.73 (67.70~87.77) | | 338 (11.83) | 85.71 (84.10~87.33) | |
| 30–39 | 890 (28.12) | 81.13 (80.06~82.19) | | 94 (30.52) | 73.37 (69.56~77.18) | | 796 (27.86) | 82.05 (80.97~83.12) | |
| 40–49 | 627 (19.81) | 81.18 (79.95~82.42) | | 78 (25.32) | 77.79 (73.97~81.60) | | 549 (19.22) | 81.66 (80.33~82.96) | |
| 50–59 | 671 (21.20) | 80.03 (79.02~81.05) | | 65 (21.10) | 74.08 (70.07~78.09) | | 606 (21.21) | 80.67 (79.65~81.70) | |
| ≥60 | 620 (19.59) | 76.39 (75.14~77.64) | | 52 (16.88) | 72.63 (67.45~77.81) | | 568 (19.88) | 76.73 (75.45~78.01) | |
| **Education level** | | | **0.0001** | | | **0.017** | | | **<0.001** |
| High school or below | 1182 (37.35) | 79.06 (78.13~79.98) | | 66 (21.43) | 68.33 (62.87~73.8) | | 1116 (39.06) | 79.69 (78.78~80.6) | |
| Bachelor or above | 1983 (62.65) | 81.27 (80.61~81.95) | | 242 (78.57) | 76.55 (74.48~78.62) | | 1741 (60.94) | 81.94 (81.24~82.63) | |
| **Marital status** | | | **<0.001** | | | 0.380 | | | **<0.001** |
| Married | 283 (89.42) | 80.15 (79.59~80.72) | | 28 (91.23) | 71.37 (62.52~80.23) | | 2549 (89.22) | 83.96 (82.21~85.70) | |
| Other | 335 (10.58) | 82.94 (81.16~84.73) | | 27 (8.77) | 75.11 (73.05~77.18) | | 308 (10.78) | 80.71 (80.12~81.29) | |
| **Ethnic** | | | 0.732 | | | 0.730 | | | 0.842 |
| Han | 3094(97.76) | 80.30 (76.01~84.58) | | 303 (98.38) | 74.75 (72.70~76.81) | | 2791 (97.69) | 81.07 (80.51~81.63) | |
| Minority | 71(2.24) | 80.45 (79.91~81.00) | | 5 (1.62) | 76.8 (60.02~93.58) | | 66 (2.31) | 80.56 (76.10~85.02) | |
| **Religion** | | | **0.008** | | | 0.354 | | | **0.011** |
| Atheist | 303 (95.96) | 75.74 (72.30~79.18) | | 29 (96.75) | 75.07 (73.05–77.09) | | 2739 (95.87) | 81.25 (80.69~81.81) | |
| Others | 128 (4.04) | 80.65 (80.10~81.19) | | 10(3.24) | 66.4 (48.82~83.98) | | 118 (4.13) | 76.53 (73.12~79.95) | |
| **Annual household income (CNY)** | | | 0.185 | | | **0.034** | | | 0.404 |
| <20,000 | 246 (7.78) | 77.94 (75.63~80.25) | | 18 (5.84) | 76.72 (70.17~83.28) | | 228 (7.98) | 78.04 (75.60~80.48) | |
| 20,000–49,999 | 510 (16.11) | 80.13 (78.69~81.57) | | 35 (11.36) | 74.6 (68.77~80.43) | | 475 (16.63) | 80.54 (79.06~82.02) | |
| 50,000–99,999 | 725 (22.91) | 79.29 (78.05~80.53) | | 78 (25.32) | 68.46 (63.73~73.19) | | 647 (22.65) | 80.60 (79.36~81.83) | |
| 100,000–199,999 | 847 (26.76) | 81.31 (80.32~82.29) | | 85 (27.60) | 77.01 (72.93~81.09) | | 762 (26.67) | 81.78 (80.80~82.77) | |
| ≥200,000 | 837 (26.45) | 81.51 (80.61~82.42) | | 92 (29.87) | 77.78 (74.94~80.62) | | 745 (26.08) | 81.97 (81.08~82.92) | |
| **BMI** | | | 0.098 | | | 0.206 | | | 0.281 |
| <18.50 | 105 (3.32) | 77.90 (74.12~81.69) | | 15 (4.87) | 74.6 (62.67–86.53) | | 90 (3.15) | 78.46 (74.49~82.42) | |
| 18.50–24.99 | 199 (63.13) | 81.01 (80.35~81.66) | | 19 (63.96) | 75.87 (73.47~78.27) | | 1801 (63.04) | 81.57 (80.90~82.24) | |
| 25.00–29.99 | 897 (28.34) | 80.02 (78.98~81.06) | | 73 (23.70) | 74.95 (71.04~78.85) | | 824 (28.84) | 80.46 (79.39~81.54) | |
| ≥30 | 165 (0.05) | 77.67 (74.92~80.43) | | 23 (0.07) | 65.13 (55.19~75.07) | | 142 (4.97) | 79.70 (77.07~82.34) | |
| **Wearing masks** | | | **0.0001** | | | 0.118 | | | **0.0001** |
| Always | 120 (38.17) | 82.16 (81.25~83.06) | | 15 (49.35) | 76.52 (73.67~79.37) | | 1056 (36.96) | 82.97 (82.03~83.91) | |
| Often | 151 (47.93) | 79.87 (79.11~80.63) | | 12 (40.91) | 74.33 (71.39~77.26) | | 1391 (48.69) | 80.38 (79.60~81.16) | |
| Seldom | 440 (13.90) | 77.74 (76.30~79.17) | | 30 (9.74) | 67.93 (59.46~76.40) | | 410 (14.35) | 78.46 (77.07~79.84) | |

(*Continued*)


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**Table 1** (Continued).

| Variables | Total % | Health Status Scores (95% CI) | *P* value[a] | Long COVID | | | Non-long COVID | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | (N=308) % | Health Status Scores (95% CI) | *P* value[b] | (N=2857) % | Health Status Scores (95% CI) | *P* value[c] |
| **Smoking** | | | 0.069 | | | 0.300 | | | 0.116 |
| Smoke | 623 (19.68) | 80.21 (78.97~81.46) | | 43 (13.96) | 68.40 (61.16~75.63) | | 580 (20.30) | 81.09 (79.89~82.28) | |
| Quit | 199 (6.29) | 78.15 (75.89~80.41) | | 28 (9.09) | 74.10 (67.69~80.52) | | 171 (5.99) | 78.81 (76.40~81.21) | |
| Never | 134 (42.43) | 80.71 (80.08~81.33) | | 23 (76.95) | 76.03 (73.88~78.17) | | 2106 (73.71) | 81.23 (80.58~81.88) | |
| **Drinking** | | | **0.008** | | | 0.091 | | | **0.016** |
| Drink | 857 (27.08) | 80.26 (79.22~81.30) | | 76 (24.68) | 76.82 (72.26~81.37) | | 781 (27.34) | 80.60 (79.54~81.65) | |
| Quit | 173 (5.47) | 76.14 (73.35~78.92) | | 23 (7.47) | 67.26 (59.21~75.31) | | 150 (5.25) | 77.50 (74.58~80.42) | |
| Never | 213 (67.46) | 80.87 (80.23~81.52) | | 20 (67.86) | 74.88 (72.55~77.20) | | 1926 (67.41) | 81.52 (80.86~82.19) | |
| **Sufficient sleeping** | | | **0.0001** | | | **0.0016** | | | **0.0001** |
| Always | 681 (21.52) | 84.74 (83.62~85.86) | | 46 (14.94) | 81.00 (76.55~85.45) | | 635 (22.23) | 85.01 (83.85~86.16) | |
| Often | 155 (49.04) | 81.24 (80.52~81.96) | | 11 (36.04) | 76.93 (73.64~80.21) | | 1441 (50.44) | 81.57 (80.84~82.30) | |
| Sometimes | 727 (22.97) | 77.43 (76.28~78.57) | | 10 (34.09) | 73.89 (70.83~76.94) | | 622 (21.77) | 78.02 (69.96~75.49) | |
| Seldom | 196 (6.2) | 71.14 (68.48~73.80) | | 44 (14.29) | 65.68 (58.83~72.53) | | 152 (5.32) | 72.72 (69.96~75.49) | |
| Never | 9 (0.28) | 66.33 (52.08~80.59) | | 2 (0.65) | 60.5 (20.16~100.84) | | 7 (0.25) | 68.00 (51.77~84.23) | |
| **Mental decompression** | | | **0.0001** | | | **0.0001** | | | **0.0001** |
| Always | 315 (0.10) | 87.13 (85.45~88.81) | | 10 (3.25) | 92.6 (86.99~98.21) | | 305 (10.68) | 86.95 (85.23~88.68) | |
| Often | 850 (0.27) | 82.40 (81.47~83.34) | | 51 (16.56) | 80.80 (77.02~84.58) | | 799 (27.97) | 82.51 (81.55~83.47) | |
| Sometimes | 1014 (32.04) | 79.39 (78.46~80.31) | | 13 (42.21) | 75.48 (72.71~78.24) | | 884 (30.94) | 79.96 (78.99~80.94) | |
| Seldom | 728 (23.00) | 78.02 (76.84~79.19) | | 97 (31.49) | 71.69 (67.64~75.74) | | 631 (22.09) | 78.99 (77.80~80.18) | |
| Never | 258 (8.15) | 76.86 (74.62~79.11) | | 20 (6.49) | 61.05 (51.66~70.44) | | 238 (8.33) | 78.19 (75.96~80.42) | |

**Notes**: 95% CI, confidence interval. CNY, China Yuan, The exchange rate, 1 dollar =7.005 CNY. [a]Differences between categories within each variable in total samples. [b]Differences between categories within each variable in long COVID samples. [c]Differences between categories within each variable in non-long COVID samples. Bolded values indicate that in this context, *P* value < 0.05 and the results are meaningful.

| Variables | Long COVID β(95% CI) | Non-long COVID β(95% CI) |
|---|---|---|
| Sex | | |
| Female (vs Male) | 0.20 ( -5.29~5.70 ) | -0.26 ( -1.67~1.14) |
| Age,years | | |
| 30-39(VS 18-29) | -8.7 ( -18.37~0.97) | -4.85 ( -7.22~-2.48) |
| 40-49(VS 18-29) | -3.36 ( -13.12~6.39 ) | -5.57 ( -8.05~-3.08) |
| 50-59(VS 18-29) | -4.00 (-13.90~5.90) | -6.96 ( -9.53~-4.39) |
| ≥60(VS 18-29) | -2.91 ( -14.15~8.34 ) | -10.30 ( -12.91~-7.7) |
| Ethnic | | |
| Han(vs Minority) | -5.31 ( -20.84~10.22 ) | -1.70 ( -5.70~2.29) |
| Marriage | | |
| married(vs others) | -6.19 ( -13.72~1.34 ) | -1.87 ( -4.20~0.47) |
| Religion | | |
| atheist (vs others) | 11.69 ( 0.25~23.13 ) | 4.12 ( 1.09~7.14) |
| BMI | | |
| 18.50-24.99(vs <18.50) | 2.80 ( -6.57~12.17 ) | 4.03 ( 0.9~7.15) |
| 25.00-29.99(vs <18.50) | 2.05 ( -7.86~11.96 ) | 4.00 ( 0.75~7.25) |
| ≥30(vs <18.50 ) | -3.19 ( -14.68~8.29 ) | 3.22 ( -0.69~7.13) |
| Annual household income(CNY) | | |
| 20000-49999(vs <20000) | 1.42 ( -8.46~11.3 ) | 1.82 ( -0.49~4.13) |
| 50000-99999(vs <20000) | -11.64 ( -20.59~-2.69 ) | 1.99 ( -0.23~4.2) |
| 100000-199999(vs <20000) | -2.52 ( -11.59~6.56 ) | 2.61 ( 0.41~4.8) |
| ≥200000(vs <20000) | -5.07 ( -14~3.86 ) | 2.59 ( 0.38~4.79) |
| Education level | | |
| bachelor or above(vs high school or below) | 7.44 ( 1.14~13.74 ) | -0.30 ( -1.64~1.03) |
| Wearing masks | | |
| often(vs always ) | -3.05 ( -7.18~1.08 ) | -1.07 ( -2.36~0.22) |
| seldom(vs always) | -7.33 ( -14.29~-0.37 ) | -0.91 ( -2.74~0.93) |
| smoking | | |
| quit smoking ( vs smoking) | 12.83 ( 3.83~21.83 ) | -1.19 ( -3.87~1.48) |
| never smoking(vs smoking) | 10.92 ( 4.23~17.62 ) | -1.09 ( -2.8~0.63) |
| Drinking | | |
| quit drinking (vs drinking) | -14.28 ( -22.68~-5.88 ) | -1.59 ( -4.32~1.13) |
| never drinking (vs drinking) | -5.56 ( -11.01~-0.1 ) | 1.33 ( -0.21~2.87) |
| Sufficient sleeping | | |
| often(vs always) | -2.15 ( -8.28~3.98 ) | -1.59 ( -3.17~-0.01) |
| sometimes(vs always) | -2.19 ( -8.5~4.12 ) | -4.95 ( -6.75~-3.14) |
| seldom(vs always) | -7.26 ( -14.91~0.4 ) | -9.85 ( -12.57~-7.12) |
| never(vs always) | -2.71 ( -27.01~21.58 ) | -15.80 ( -26.72~-4.88) |
| Mental decompression | | |
| often(vs always) | -9.03 ( -20.68~2.61 ) | -2.31 ( -4.48~-0.15) |
| sometimes(vs always) | -14.04 ( -25.15~-2.93 ) | -4.22 ( -6.35~-2.10) |
| seldom(vs always) | -16.6 ( -28.15~-5.05 ) | -4.47 ( -6.71~-2.23) |
| never(vs always) | -25.4 ( -38.82~-11.98 ) | -4.86 ( -7.51~-2.21) |

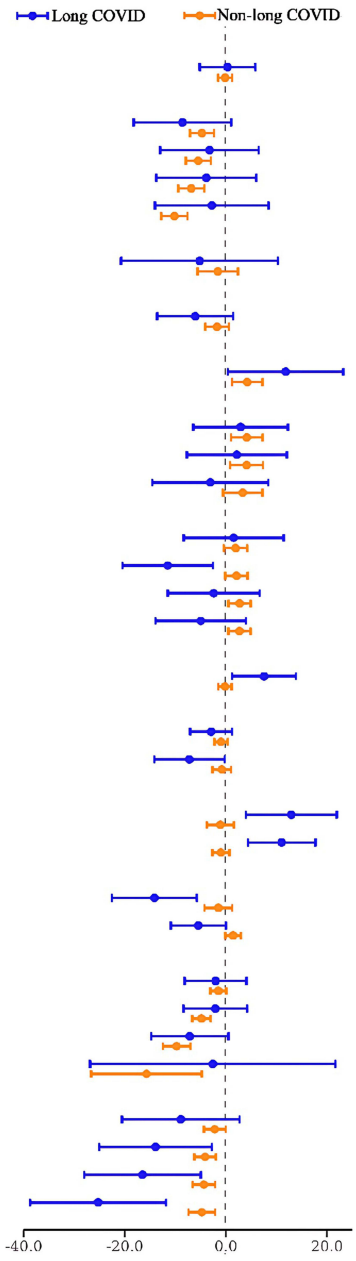


**Figure 2** Factors influencing the health status of long COVID and non-long COVID cases.
**Notes**: 95% CI, confidence interval. CNY, China Yuan, The exchange rate,1 dollar=7.055 CNY. β, Adjusted for sex, age, ethnic, marriage, religion, BMI, Annual household income, education level, wearing masks, smoking, drinking, sufficient sleeping, mental decompression.

model, the 95% CI did not include 0, suggesting that the mediating effect of lifestyle was confirmed. Furthermore, the results indicated that there was a significant correlation between long COVID and health status scores (c'=6.0486, $P$<0.001), as well as between lifestyle and health status scores (b=−0.6349, $P$<0.001). This suggests that lifestyle partially mediated the relationship between long COVID and health status scores, with a mediating effect estimated to be 0.2249 (95% CI: 0.077~0.410) (see Table S2).

## Results of Propensity Score Matching

A total of 281 pairs of 562 individuals were matched from the population sample of 3165. The covariates included education level, wearing masks, and sufficient sleeping (see Table S3). Based on the matched data, the differences in the health status scores between long and non-long COVID cases are shown in Figure 4. After PSM matching, the health

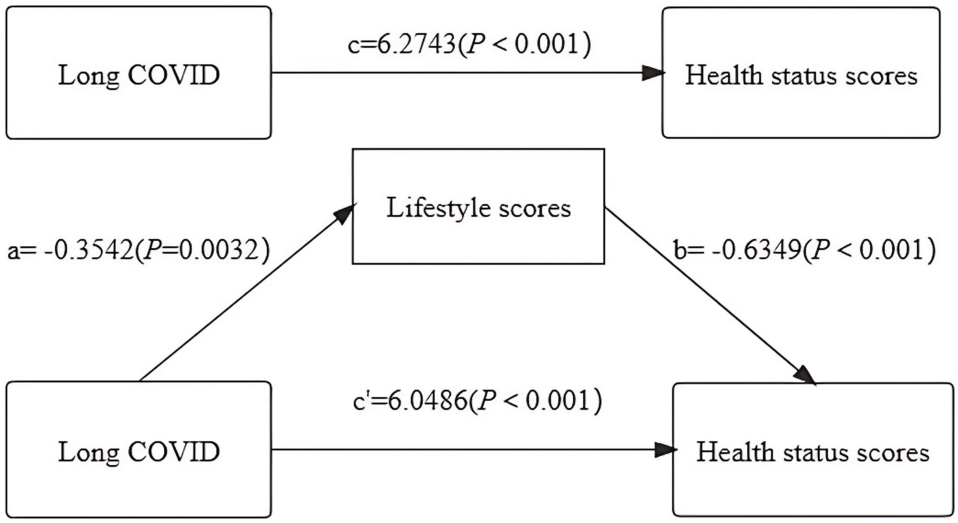


**Figure 3** The mediating effect of lifestyle scores.
**Notes**: a long COVID predicts lifestyle scores. b lifestyle scores predict health status scores. c long COVID predicts health status scores. c' long COVID and lifestyle scores co-predict health status scores.

status score of long COVID cases 73.43 (95% CI: 72.29~76.57) was still lower than that of non-long COVID cases 79.03 (95% CI: 77.22~80.83). Before and after matching, the difference in the health status score between the long COVID cases and non-long COVID cases was 5.59, as shown in Figure 4. (Common support domain of PSM for long COVID and non-long COVID cases is shown in Figure S2).

The above results can be used to form a possible mechanistic pathway for all the findings of this study, which can be seen in detail in Figure 5.

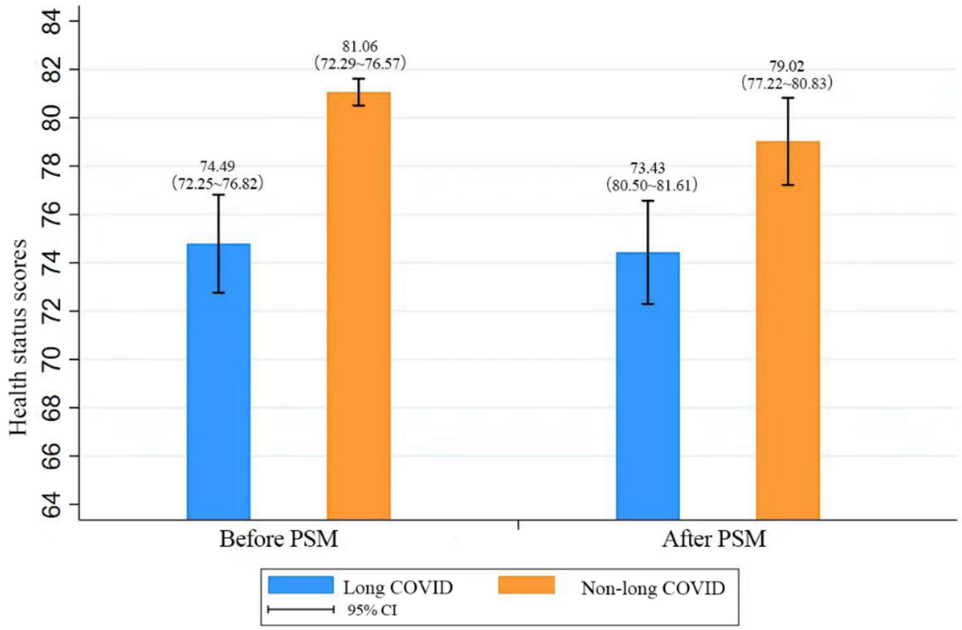


**Figure 4** The health status scores between long COVID and non-long COVID cases pre- and post-PSM.
**Notes**: 95% CI, confidence interval. PSM, Propensity Score Matching.

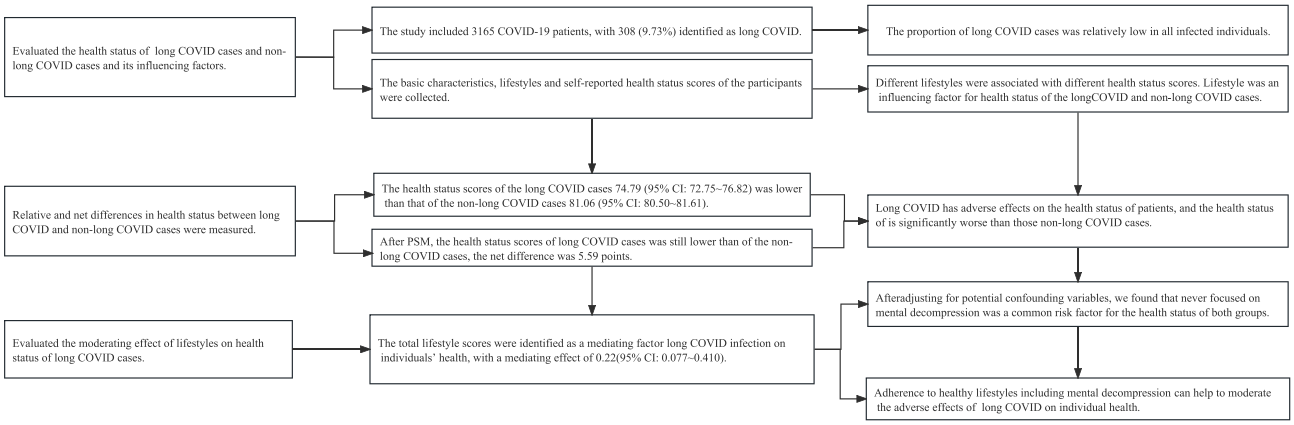


**Figure 5** The possible mechanistic pathway for the findings of this study. 95% CI, confidence interval.

# Discussion

## Primary Findings

Our results showed that the incidence of what we termed long COVID was at a low level. The overall health status score of the patients was 80.45, but the health status scores of long COVID cases was lower than that of non-long COVID cases. Even after propensity score matching, long COVID cases still had lower health status scores than non-long COVID cases. We found that the lifestyles of COVID-19 patients, including wearing masks, smoking, drinking, sufficient sleeping and mental decompression, was associated with their health status. Healthy lifestyles play a moderating role in improving the health status of long COVID cases.

## Comparison with Previous Studies

One study showed that the prevalence of long COVID was between 10% and 15%,[24] and a previous study from China showed that 8.89% of infected individuals self-reported long COVID symptoms,[25] which is basically consistent with the results of our study (9.73%). However, other studies have reported different prevalence rates. For example, a study from Italy showed that 87.4% of people who recovered from COVID-19 reported at least one persistent symptom (such as asthma and fatigue),[9] a study from the United States showed that 14.7% of patients had varying degrees of prolonged COVID-19 symptoms,[26] and a study from the Faroe Islands showed that 39% of patients developed long COVID symptoms.[27] This difference in research results is caused by a variety of factors, mainly because the definition of long COVID has not been formally determined, and the definitions and standards adopted by different studies are inconsistent. In addition, the different treatment statuses received by the hospitalized and non-hospitalized populations,[28] the difference in vaccination,[29] and the different immune response of the people[30] also lead to the inconsistent results. Moreover, our questionnaires were self-reported by infected persons, who tended to report the symptoms that boded them most, and were not professionally validated by health care providers. The patients may also attribute symptoms to their illness rather than their infection, and recall bias can occur when reporting the number of days. Therefore, it can be speculated that our survey results are conservative and may be at the lower limit of prevalence. However, we do not think this discrepancy seriously undermines the value of our findings, because most persistent symptoms are subjective, such as fatigue, and are difficult to verify objectively, even when assessed by a health care professional.

This study suggests that the effects of long COVID on the health status of infected individuals are common and persistent, which is consistent with the findings of previous studies.[31,32] The health status of COVID-19 patients differs significantly by having long COVID, with long COVID cases having worse health status, which is similar to the findings of previous studies.[18,33,34] The main reason is that the long-term persistent symptom cluster caused by long COVID includes respiratory sequelae, mental health disorders, cardiovascular diseases,[35] gastrointestinal diseases, fatigue, hypertension,[36] musculoskeletal pain and anemia,[37] which disrupt almost all aspects of daily life of infected people. In the absence of effective treatment, the persistence of sequelae reduces the quality of life of COVID-19 patients and

negatively impacts their health status.[38] Another reason for the worse health status of long COVID cases may be that compared with acutely infected patients, long COVID cases are not prioritized as a group that does not need to be hospitalized for dynamic monitoring, resulting in their lack of close monitoring or guidance during the recovery process.[39] Moreover, given the huge scale of the COVID-19 epidemic, even if the proportion of long COVID cases is very low, it will cause a significant burden of long-term illness among COVID-19 patients.[40]

In this study, we found that the health status of long COVID cases was associated with smoking, drinking, and mental decompression. Compared with smokers, ex-smokers and never-smokers had better health status, which is consistent with a previous finding.[39] This may be because smoking is a potential risk factor for long COVID,[41] which can worsen the health status of the infected person. Since SARS-CoV-2 is mainly transmitted from person to person through respiratory droplets,[42] smoking can increase the burden on the respiratory system and lungs and the symptoms of virus infection, weaken the immune and cardiovascular systems of infected people, increase their susceptibility to various health complications,[18] and have a negative impact on the health status of infected individuals.

Among long COVID cases, ex-drinkers and those who never drank did not show better health than drinkers. We consider that the most important reason for this result may be due to the infection itself because such an association was not found in non-long COVID cases. Moreover, alcohol has both advantages and disadvantages for human health. Although studies have shown that heavy drinking or frequent alcohol abuse is positively correlated with many diseases including cardiovascular and cerebrovascular diseases, which is not conducive to personal health,[43,44] there is also evidence that compared with moderate drinkers, non-drinkers have worse health conditions.[45]

The health status of non-long COVID cases is related to sufficient sleeping, and less adequate sleep was associated with poorer health status, consistent with a previous study.[46] This may be due to physical discomfort caused by symptoms during the acute infection phase[47] and the negative effects of restrictive measures including "social distancing strategy" to contain the spread of infection.

We did not find gender differences in the health status of the COVID-19 patients, but we found that people who never paid attention to mental decompression had the worst health status, regardless of whether they were long COVID cases or not. This is consistent with the results of a previous study.[22] This may be due to the disruptive social changes caused during the COVID-19 epidemic, which exacerbated the mental stress of individuals, and the increase in public restrictions during the epidemic, the pressure of hospital medical care, the fear of infecting others, and the stigma increased the psychological stress of COVID-19 patients, which had a considerable negative impact on their health status.[48,49]

Although any one of these factors can reduce health status individually, the combination of all these factors is most likely to have an additive effect,[50] suggesting a link between lifestyle and the health status of patients. Despite the current help of vaccines and pharmaceutical interventions, the actual route of infection in humans cannot be fully simulated,[51] so adherence to a healthy lifestyle is crucial. The results of this study could show that a healthy lifestyle has a positive effect on the health of patients, especially mental health support for individuals who recover from COVID-19, can help regulate the harm of long COVID to the health of individuals.[52]

## Strengths and Limitations

This study has several strengths. First, this is the first national survey after the "Class B epidemic and B management" policy was adjusted in mainland China. The timeliness of the findings helps to deepen the understanding of the long-term harm of COVID-19 infection. Given the significant mediating effect, healthy lifestyles should be considered a cost-effective approach to cope with the continued low level of the COVID-19 epidemic. Second, the PSM method was used to control for confounding factors and ensure the reliability and robustness of the absolute difference in health status between long COVID and non-long COVID cases in this study, which was better than previous similar studies.

This study has several limitations. First, COVID-19 infection and health status scores were based on self-reports, which caused recollection and subjectivity bias. Second, the factors affecting the health status of COVID-19 patients are complex, which means that in addition to the positive mediating effect of lifestyle identified in this study, there are other unknown covariates to be uncovered. Finally, although PSM was used in this research to avoid the influence of some confounding variables, the confounding effect of unknown covariates was difficult to eliminate.

## Conclusion

The proportion of long COVID cases was relatively low in all infected individuals. Education level, wearing masks, smoking, drinking and mental decompression were influencing factors. The health status of long COVID cases is significantly worse, and it is necessary to strengthen the follow-up of this population. Given the positive moderating role of healthy lifestyles in improving the health status of long COVID cases, healthy lifestyles including mental decompression should still be considered the most active prevention strategy at the current low epidemic level of COVID-19.

## Data Sharing Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

## Ethics Statement

The study complied with the Declaration of Helsinki. Participants were informed of the benefits and risks of participating in this study, and they provided informed consent. All data were used merely for research purposes. This study was approved by the Life Science Ethics Review Committee of Zhengzhou University (2021-01-12-05).

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## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

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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