



Global Percentage of Asymptomatic SARS-CoV-2 Infections Among the Tested Population and Individuals With Confirmed COVID-19 Diagnosis

A Systematic Review and Meta-analysis

Qiyue Ma, PhD; Jue Liu, PhD; Qiao Liu, BD; Liangyu Kang, BD; Runqing Liu, BD; Wenzhan Jing, PhD; Yu Wu, MD; Min Liu, PhD

Abstract

IMPORTANCE Asymptomatic infections are potential sources of transmission for COVID-19.

OBJECTIVE To evaluate the percentage of asymptomatic infections among individuals undergoing testing (tested population) and those with confirmed COVID-19 (confirmed population).

DATA SOURCES PubMed, EMBASE, and ScienceDirect were searched on February 4, 2021.

STUDY SELECTION Cross-sectional studies, cohort studies, case series studies, and case series on transmission reporting the number of asymptomatic infections among the tested and confirmed COVID-19 populations that were published in Chinese or English were included.

DATA EXTRACTION AND SYNTHESIS This meta-analysis was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. Random-effects models were used to estimate the pooled percentage and its 95% CI. Three researchers performed the data extraction independently.

MAIN OUTCOMES AND MEASURES The percentage of asymptomatic infections among the tested and confirmed populations.

RESULTS Ninety-five unique eligible studies were included, covering 29 776 306 individuals undergoing testing. The pooled percentage of asymptomatic infections among the tested population was 0.25% (95% CI, 0.23%-0.27%), which was higher in nursing home residents or staff (4.52% [95% CI, 4.15%-4.89%]), air or cruise travelers (2.02% [95% CI, 1.66%-2.38%]), and pregnant women (2.34% [95% CI, 1.89%-2.78%]). The pooled percentage of asymptomatic infections among the confirmed population was 40.50% (95% CI, 33.50%-47.50%), which was higher in pregnant women (54.11% [95% CI, 39.16%-69.05%]), air or cruise travelers (52.91% [95% CI, 36.08%-69.73%]), and nursing home residents or staff (47.53% [95% CI, 36.36%-58.70%]).

CONCLUSIONS AND RELEVANCE In this meta-analysis of the percentage of asymptomatic SARS-CoV-2 infections among populations tested for and with confirmed COVID-19, the pooled percentage of asymptomatic infections was 0.25% among the tested population and 40.50% among the confirmed population. The high percentage of asymptomatic infections highlights the potential transmission risk of asymptomatic infections in communities.

JAMA Network Open. 2021;4(12):e2137257. doi:10.1001/jamanetworkopen.2021.37257

Key Points

Question What is the percentage of asymptomatic individuals with positive test results for SARS-CoV-2 among tested individuals and those with confirmed COVID-19 diagnosis?

Findings In this systematic review and meta-analysis of 95 unique studies with 29 776 306 individuals undergoing testing, the pooled percentage of asymptomatic infections was 0.25% among the tested population and 40.50% among the population with confirmed COVID-19.

Meaning The high percentage of asymptomatic infections from this study highlights the potential transmission risk of asymptomatic infections in communities.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

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Introduction

COVID-19, the disease caused by SARS-CoV-2, was first reported in December 2019.¹ Globally, as of January 28, 2021, there have been 100 455 529 confirmed cases, including 2 166 440 deaths.² The disease course of COVID-19 ranges from asymptomatic to mild respiratory infections to pneumonia and even to acute respiratory distress syndrome.³ Patients with no symptoms at screening point were defined as having asymptomatic infections, which included infected people who have not yet developed symptoms but go on to develop symptoms later (presymptomatic infections), and those who are infected but never develop any symptoms (true asymptomatic or covert infections).^{4,5} Owing to the absence of symptoms, these patients would not seek medical care and could not be detected by temperature screening. Presymptomatic transmission will also make temperature screening less effective.⁶ Only extensive testing and close contact tracing could lead to identification of more asymptomatic infections.⁷

Unlike SARS, which had little known transmission from asymptomatic patients, evidence showed that asymptomatic patients were a potential source of transmission of COVID-19.^{3,6} A previous study⁸ showed that the upper respiratory viral loads in asymptomatic patients were comparable to those in symptomatic patients. Meanwhile, the highest viral load in throat swabs at the time of symptom onset indicated that infectiousness peaked on or before symptom onset.⁹ Moreover, studies showed that asymptomatic infections might have contributed to transmission among households, nursing facilities, and clusters.¹⁰⁻¹³ As the pandemic has been contained in many countries and regions, travel restrictions have been lifted and public places have reopened. Asymptomatic infections should be considered a source of COVID-19 infections that play an important role in the spread of the virus within community as public life gradually returns to normal. The management of asymptomatic carriers was essential for preventing cluster outbreaks and transmission within a community.

However, comprehensive evaluation of the percentage of asymptomatic infections among the tested population and the population with confirmed COVID-19 (confirmed population) is limited. Current results from different studies^{3,5,7,8,10,11} varied considerably owing to different study design and study population. Thus, we conducted a meta-analysis to better understand the global percentage of asymptomatic infections among the tested and confirmed COVID-19 populations. Our results could be useful for strategies to reduce transmission by asymptomatic infections.

Methods

Search Strategy

We conducted the meta-analysis following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. This review was not registered. Three researchers (Q.L., L.K., and R.L.) searched the published studies on February 4, 2021, through PubMed, EMBASE, and ScienceDirect without language restriction. The search terms used included *COVID-19*, *coronavirus*, *SARS-CoV-2*, *asymptomatic transmission*, *asymptomatic infection*, *asymptomatic proportion*, *asymptomatic case*, *asymptomatic cases*, *asymptomatic contact*, *asymptomatic ratio*, *asymptomatic people*, *asymptomatic patients*, and *asymptomatic patient*. The detailed search strategies are shown in eMethods 1 in the Supplement. Three researchers (Q.L., L.K., and R.L.) reviewed the titles, abstracts, and full texts of articles independently and identified additional studies from the reference lists. Disagreements were resolved by 2 other reviewers (W.J. and Y.W.).

Selection Criteria

Asymptomatic individuals with positive test results for SARS-CoV-2 (asymptomatic infections) were defined as those who did not present any symptoms at the time of SARS-CoV-2 testing or diagnosis.¹⁴ Individuals with a confirmed COVID-19 diagnosis were defined as those who had a throat swab or other specimen with positive results for SARS-CoV-2 using a real-time reverse-transcription

polymerase chain reaction assay. Inclusion criteria consisted of (1) studies reporting the number of asymptomatic infections, tested population, and confirmed population and (2) cross-sectional studies, cohort studies, case series studies, and case series on transmission. Exclusion criteria consisted of (1) reviews, systematic reviews, and meta-analysis; (2) duplicate publications; (3) preprints; (4) multiple studies reporting on overlapping participants (the study with more information was included); (5) articles with ambiguous definition of asymptomatic infections; and (6) articles not written in English or Chinese.

Data Extraction and Quality Assessment

Three researchers (Q.L., L.K., and R.L.) performed the data extraction independently. Data were extracted for the first author, date of publication, study location, number of tested individuals, number of individuals with confirmed COVID-19, and number of asymptomatic infections. The ratio of male to female individuals (MFR) and mean age of study participants were gathered if available. The quality of studies included in the meta-analysis was assessed using the Joanna Briggs Institute Prevalence Critical Appraisal Tool¹⁵ for cross-sectional studies and the Newcastle-Ottawa scale¹⁶ for cohort studies (eMethods 2 in the [Supplement](#)). Case series on transmission were assessed using the quality assessment tool developed by Yanes-Lane et al.¹⁷ Two researchers (Q.L. and L.K.) performed the quality assessment independently. Disagreements were resolved by 2 other reviewers (W.J. and Y.W.). Outcomes of interest included the percentages of asymptomatic infections among the tested and the confirmed populations.

Statistical Analysis

We performed a meta-analysis to estimate the pooled percentage of asymptomatic infections among the tested and confirmed populations. Untransformed percentages and DerSimonian and Laird random-effects models¹⁸ were used to calculate the pooled percentage and its 95% CI. The heterogeneity among studies was assessed using I^2 values.¹⁹ We performed subgroup analyses by study location (Africa, Asia, Europe, North America, and South America), countries' development level (developed vs developing), study population (air or cruise travelers, close contact, community residents, health care workers or in-hospital patients, nursing home residents or staff, and pregnant women), publication period (June 2020 and earlier vs July 2020 and later), sample size for the tested population (1-99, 100-999, 1000-9999, and $\geq 10\ 000$), sample size for the confirmed population (1-99, 100-499, and ≥ 500), study design (case series, case series on transmission, cohort studies, and cross-sectional studies), study quality (low, moderate, and high), MFR (0 to <0.5 , 0.5 to <1.0 , 1.0 to <1.5 , and ≥ 1.5), and mean age (<20 , 20-39, 40-59, and ≥ 60 years). Publication bias was assessed by funnel plot and the Egger regression test.²⁰ We performed 3 sensitivity analyses to test the robustness of our results, by using the Knapp-Hartung adjustments²¹ to calculate the 95% CIs around the pooled effects, by excluding 3 studies with a tested population more than 200 000 and studies with low quality. Two-sided $P < .05$ indicated statistical significance. All analyses were performed using R, version 4.0.0 (R Project for Statistical Computing).

Results

We identified 2860 studies through database search and the reference lists of articles and reviews. Of these, 282 studies underwent full-text review. Ninety-five studies with information concerning the percentage of asymptomatic infections among the tested and confirmed populations were included in the final analysis^{12,22-115} (**Figure 1**).

Among these studies, 44 (46.32%) were cross-sectional studies, 41 (43.16%) were cohort studies, 7 (7.37%) were case series, and 3 (3.16%) were case series on transmission studies. Thirty-five studies (36.84%) were conducted in Europe; 32 (33.68%), in North America; and 25 (26.32%), in Asia. Seventy-four studies (77.89%) were conducted in developed countries. Thirty-seven studies (38.95%) were conducted among health care workers or in-hospital patients; 17 (17.89%), among

nursing home residents or staff; 14 (14.74%), among community residents; 13 (13.68%), among pregnant women; 8 (8.42%), among air or cruise travelers; and 6 (6.32%), among close contacts. Twenty-one studies (22.11%) were published in June or before; 74 (77.89%), in July and after. Forty-nine studies (51.58%) had sample size of 100 to 1000. Fifty-three studies (55.79%) were assessed as low quality; 17 (17.89%), high quality; and 25 (26.32%), moderate quality (Table). For cross-sectional studies, low-quality studies were mostly those without random sampling or with 2 or more biases (selection bias, reporting bias, or detection bias). For cohort studies, low-quality studies were mostly those with 1 or more biases.

Percentage of Asymptomatic Infections Among the Tested Population

Ninety-five studies were included in the meta-analysis for the percentage of asymptomatic infections among the tested population, covering 29 776 306 tested individuals, among whom 11 516 had asymptomatic infections. The pooled percentage of asymptomatic infections among the tested population was 0.25% (95% CI, 0.23%-0.27%), with high heterogeneity among studies ($I^2 = 99%$; $P < .001$) (eFigure 1 in the Supplement).

Among tested individuals in different study populations, the pooled percentage of asymptomatic infections was 4.52% (95% CI, 4.15%-4.89%) in nursing home residents or staff, 2.02% (95% CI, 1.66%-2.38%) in air or cruise travelers, 2.34% (95% CI, 1.89%-2.78%) in pregnant women, 1.46% (95% CI, 1.05%-1.88%) in close contacts, 0.75% (95% CI, 0.60%-0.90%) in health care workers or in-hospital patients, and 0.40% (95% CI, 0.18%-0.62%) in community residents. The pooled percentage of asymptomatic infections was 0.90% (95% CI, 0.87%-0.93%) in Europe, 0.47% (95% CI, 0.39%-0.54%) in North America, and 0.05% (95% CI, 0.04%-0.07%) in Asia. The pooled percentage was higher in developed countries (0.70% [95% CI, 0.67%-0.73%]), studies published in July or later (0.29% [95% CI, 0.27%-0.31%]), studies with a sample size of less than 100 (6.74% [95% CI, 4.69%-8.80%]), and cohort studies (2.98% [95% CI, 2.68%-3.29%]). In studies with MFR of 0.5 to less than 1.0, the pooled percentage was higher (3.91%; [95% CI, 3.14%-4.68%]). The pooled percentage was higher when the mean age of the study population was 60 years or older (3.69% [95% CI, 2.99%-4.39%]) (Figure 2).

Figure 1. Flow Diagram of Study Selection

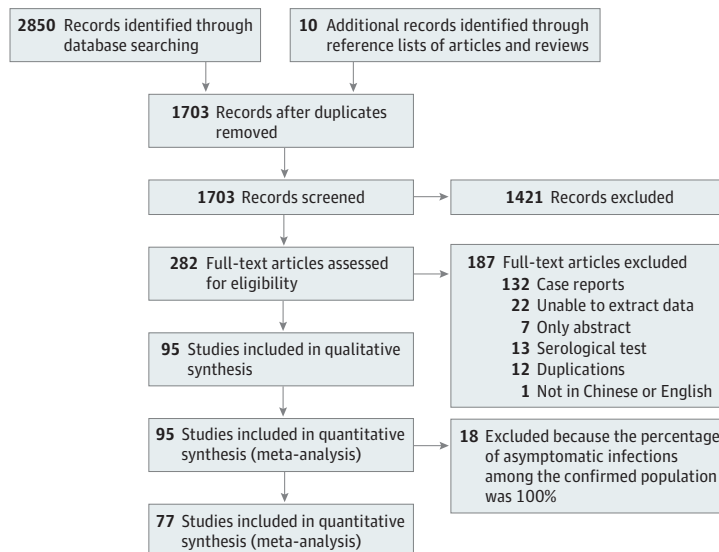


Table. Characteristics of the Studies Included for Meta-analysis

| Source | Country | Study design | Time of publication | Population group | No. tested individuals | No. confirmed individuals | No. asymptomatic infections | Quality |
|-----------------------------------|----------------------|-----------------------------|---------------------|---|------------------------|---------------------------|-----------------------------|----------|
| Abdelmoniem et al ²² | Egypt | Cross-sectional | January 2020 | Health care workers or in-hospital patients | 203 | 29 | 29 | Low |
| Abeyuriya et al ²³ | UK | Cross-sectional | September 2020 | Pregnant women | 180 | 7 | 6 | Low |
| Akbarialiabad et al ²⁴ | Iran | Cross-sectional | September 2020 | Health care workers or in-hospital patients | 1805 | 86 | 19 | Low |
| Al-Qahtani et al ²⁵ | Kingdom of Bahrain | Cohort | November 2020 | Air or cruise travelers | 2714 | 188 | 116 | High |
| Al-Shamsi et al ²⁶ | United Arab Emirates | Cohort | November 2020 | Health care workers or in-hospital patients | 109 | 32 | 6 | Low |
| Arnold et al ²⁷ | US | Cross-sectional | January 2021 | Health care workers or/in-hospital patients | 2882 | 103 | 38 | Moderate |
| Arons et al ¹² | US | Cross-sectional | April 2020 | Nursing home residents or staff | 76 | 48 | 27 | Moderate |
| Aslam et al ²⁸ | US | Cohort | January 2020 | Health care workers or in-hospital patients | 11 622 | 69 | 42 | Low |
| Bayle et al ²⁹ | France | Cross-sectional | January 2021 | Nursing home residents or staff | 241 | 32 | 24 | Moderate |
| Bender et al ³⁰ | US | Cohort | September 2020 | Pregnant women | 318 | 8 | 8 | Moderate |
| Bianco et al ³¹ | US | Cross-sectional | May 2020 | Pregnant women | 155 | 24 | 24 | Low |
| Blain et al ³² | US | Case series | July 2020 | Nursing home residents or staff | 113 | 44 | 8 | Moderate |
| Blitz et al ³³ | US | Cohort | August 2020 | Pregnant women | 382 | 71 | 45 | Low |
| Blumberg et al ³⁴ | US | Cohort | October 2020 | Health care workers or in-hospital patients | 1198 | 7 | 6 | Low |
| Bosworth et al ³⁵ | UK | Cross-sectional | July 2020 | Health care workers or in-hospital patients | 1282 | 53 | 16 | Moderate |
| Cao et al ³⁶ | China | Cross-sectional | November 2020 | Community residents | 9 865 404 | 300 | 300 | High |
| Carroll et al ³⁷ | Ireland | Cohort | October 2020 | Close contact | 4586 | 310 | 209 | Moderate |
| Cattelan et al ³⁸ | Italy | Cohort | August 2020 | Health care workers or in-hospital patients | 7595 | 395 | 109 | Low |
| Cloutier et al ³⁹ | Canada | Cross-sectional | August 2020 | Community residents | 330 | 6 | 6 | Low |
| Corcorran et al ⁴⁰ | US | Cohort | August 2020 | Health care workers or in-hospital patients | 25 | 10 | 4 | Low |
| Deng et al ⁴¹ | China | Case series on transmission | October 2020 | Close contact | 347 | 27 | 1 | High |
| Dora et al ⁴² | US | Cross-sectional | May 2020 | Nursing home residents or staff | 235 | 27 | 18 | Low |
| Duan et al ⁴³ | China | Cross-sectional | September 2020 | Health care workers or/in-hospital patients | 4729 | 4 | 4 | Moderate |
| Figueiredo et al ⁴⁴ | Portugal | Cohort | October 2020 | Pregnant women | 184 | 11 | 9 | Low |
| Goldfarb et al ⁴⁵ | US | Cross-sectional | May 2020 | Pregnant women | 757 | 20 | 9 | Moderate |
| Graham et al ⁴⁶ | UK | Cross-sectional | September 2020 | Nursing home residents or staff | 464 | 129 | 54 | Moderate |
| Grechukhina et al ⁴⁷ | US | Cohort | November 2020 | Pregnant women | 1567 | 141 | 44 | High |
| Gruskay et al ⁴⁸ | US | Cohort | June 2020 | Health care workers or in-hospital patients | 99 | 12 | 7 | Low |
| Han et al ⁴⁹ | China | Cross-sectional | June 2020 | Community residents | 29 299 | 18 | 18 | Low |
| Harada et al ⁵⁰ | Japan | Cohort | December 2020 | Health care workers or in-hospital patients | 1259 | 79 | 33 | Low |
| Hcini et al ⁵¹ | France | Cohort | February 2020 | Pregnant women | 507 | 137 | 103 | Low |
| Hoxha et al ⁵² | Belgium | Cross-sectional | July 2020 | Nursing home residents or staff | 280 427 | 8325 | 6244 | Moderate |
| Hung et al ⁵³ | China | Case series | September 2020 | Air or cruise travelers | 215 | 9 | 6 | High |
| Ibrahim et al ⁵⁴ | Indonesia | Case series | August 2020 | Health care workers or in-hospital patients | 4617 | 582 | 55 | Low |
| Kennelly et al ⁵⁵ | Ireland | Cohort | September 2020 | Nursing home residents or staff | 2968 | 1105 | 290 | Low |
| Kessler et al ⁵⁶ | Germany | Cross-sectional | December 2020 | Health care workers or in-hospital patients | 689 | 1 | 1 | Moderate |
| Kimball et al ⁵⁷ | US | Cross-sectional | April 2020 | Nursing home residents or staff | 76 | 23 | 13 | Moderate |

(continued)

Table. Characteristics of the Studies Included for Meta-analysis (continued)

| Source | Country | Study design | Time of publication | Population group | No. tested individuals | No. confirmed individuals | No. asymptomatic infections | Quality |
|-------------------------------------|----------------|-----------------------------|---------------------|---|------------------------|---------------------------|-----------------------------|----------|
| Kirschblum et al ⁵⁸ | US | Cohort | July 2020 | Health care workers or in-hospital patients | 103 | 12 | 12 | Low |
| Krüger et al ⁵⁹ | Germany | Cohort | January 2021 | Health care workers or in-hospital patients | 6940 | 27 | 7 | Low |
| Kwon et al ⁶⁰ | South Korea | Cross-sectional | July 2020 | Health care workers or in-hospital patients | 2087 | 42 | 6 | Low |
| LaCourse et al ⁶¹ | US | Cohort | May 2020 | Pregnant women | 230 | 13 | 1 | Low |
| Ladhani et al ⁶² | UK | Cohort | September 2020 | Nursing home residents or staff | 518 | 158 | 97 | High |
| Lan et al ⁶³ | US | Cross-sectional | November 2020 | Community residents | 104 | 21 | 16 | Moderate |
| Lavezzo et al ⁶⁴ | Italy | Cross-sectional | July 2020 | Community residents | 2812 | 73 | 29 | Moderate |
| Livingston et al ⁶⁵ | UK | Cohort | October 2020 | Health care workers or in-hospital patients | 344 | 131 | 16 | Moderate |
| Lombardi et al ⁶⁶ | Italy | Cohort | June 2020 | Health care workers or in-hospital patients | 1573 | 139 | 28 | Low |
| Ly et al ⁶⁷ | France | Cross-sectional | November 2020 | Nursing home residents or staff | 1691 | 226 | 46 | Moderate |
| Lytras et al ⁶⁸ | Greece | Cross-sectional | April 2020 | Air or cruise travelers | 783 | 40 | 35 | Low |
| Maechler et al ⁶⁹ | Germany | Cross-sectional | December 2020 | Community residents | 4333 | 333 | 14 | High |
| Marossy et al ⁷⁰ | UK | Cross-sectional | September 2020 | Nursing home residents or staff | 2455 | 160 | 115 | Moderate |
| Marschner et al ⁷¹ | Germany | Cross-sectional | July 2020 | Health care workers or in-hospital patients | 139 | 1 | 1 | Low |
| Martinez-Fierro et al ⁷² | Mexico | Cross-sectional | October 2020 | Close contact | 81 | 34 | 5 | Low |
| Massarotti et al ⁷³ | Italy | Cross-sectional | August 2020 | Pregnant women | 333 | 7 | 6 | Low |
| Mattar et al ⁷⁴ | Caribbean | Cross-sectional | December 2020 | Close contact | 686 | 35 | 18 | Low |
| Menting et al ⁷⁵ | Germany | Cross-sectional | January 2020 | Health care workers or in-hospital patients | 1185 | 11 | 2 | Low |
| Migueres et al ⁷⁶ | France | Cross-sectional | September 2020 | Health care workers or in-hospital patients | 123 | 44 | 17 | Low |
| Milani et al ⁷⁷ | Italy | Cross-sectional | June 2020 | Community residents | 197 | 21 | 21 | Moderate |
| Nishiura et al ⁷⁸ | Japan | Cross-sectional | May 2020 | Air or cruise travelers | 565 | 13 | 4 | Low |
| Ochiai et al ⁷⁹ | Japan | Cross-sectional | June 2020 | Pregnant women | 52 | 2 | 2 | Low |
| Olalla et al ⁸⁰ | Spain | Cross-sectional | August 2020 | Health care workers or in-hospital patients | 498 | 2 | 2 | Low |
| Olmos et al ⁸¹ | Chile | Cross-sectional | January 2021 | Health care workers or in-hospital patients | 413 | 14 | 14 | Low |
| Park et al ⁸² | South Korea | Cross-sectional | April 2020 | Community residents | 1143 | 97 | 8 | High |
| Park et al ⁸³ | Korea | Cohort | December 2020 | Air or cruise travelers | 39 | 30 | 4 | Low |
| Patel et al ⁸⁴ | United States | Cohort | June 2020 | Nursing home residents or staff | 126 | 35 | 14 | Low |
| Pavli et al ⁸⁵ | Greece | Case series on transmission | September 2020 | Air or cruise travelers | 891 | 5 | 2 | High |
| Petersen et al ⁸⁶ | United Kingdom | Cross-sectional | October 2020 | Community residents | 36 061 | 115 | 88 | Moderate |
| Puckett et al ⁸⁷ | United States | Cohort | December 2020 | Health care workers or in-hospital patients | 227 | 2 | 2 | Low |
| Ralli et al ⁸⁸ | Italy | Cohort | December 2020 | Community residents | 298 | 12 | 9 | Low |
| Rashid-Abdi et al ⁸⁹ | Sweden | Cohort | November 2020 | Health care workers or in-hospital patients | 131 | 21 | 1 | Low |
| Ren et al ⁹⁰ | China | Cohort | February 2021 | Air or cruise travelers | 19 398 384 | 3103 | 1749 | High |
| Rincón et al ⁹¹ | Spain | Cohort | September 2020 | Health care workers or in-hospital patients | 192 | 36 | 14 | Low |
| Roxby et al ⁹² | United States | Cohort | May 2020 | Nursing home residents or staff | 80 | 3 | 2 | Low |
| Sacco et al ⁹³ | France | Cohort | November 2020 | Nursing home residents or staff | 179 | 63 | 12 | Low |
| Santos et al ⁹⁴ | Portugal | Cross-sectional | December 2020 | Health care workers or in-hospital patients | 8037 | 211 | 47 | Low |
| Scheier et al ⁹⁵ | Switzerland | Cross-sectional | February 2021 | Health care workers or in-hospital patients | 2807 | 68 | 8 | High |

(continued)

Table. Characteristics of the Studies Included for Meta-analysis (continued)

| Source | Country | Study design | Time of publication | Population group | No. tested individuals | No. confirmed individuals | No. asymptomatic infections | Quality |
|-------------------------------|-----------------|-----------------------------|---------------------|---|------------------------|---------------------------|-----------------------------|----------|
| Shah et al ⁹⁶ | US | Case series | July 2020 | Health care workers or in-hospital patients | 625 | 1 | 1 | Low |
| Shi et al ⁹⁷ | US | Cohort | October 2020 | Nursing home residents or staff | 389 | 146 | 66 | Moderate |
| Singer et al ⁹⁸ | US | Case series | October 2020 | Health care workers or in-hospital patients | 4751 | 18 | 10 | High |
| Tang et al ⁹⁹ | China | Cross-sectional | July 2020 | Health care workers or in-hospital patients | 1027 | 52 | 13 | High |
| Tang et al ¹⁰⁰ | US | Cohort | November 2020 | Nursing home residents or staff | 1970 | 752 | 424 | High |
| Temkin et al ¹⁰¹ | Israel | Cross-sectional | October 2020 | Health care workers or in-hospital patients | 522 | 1 | 1 | Low |
| Trahan et al ¹⁰² | Canada | Cohort | November 2020 | Pregnant women | 803 | 41 | 11 | Low |
| Tsou et al ¹⁰³ | China | Case series | November 2020 | Community residents | 17 935 | 100 | 10 | Moderate |
| van Buul et al ¹⁰⁴ | The Netherlands | Cohort | December 2020 | Nursing home residents or staff | 839 | 25 | 6 | High |
| Varnell et al ¹⁰⁵ | US | Cohort | January 2021 | Health care workers or in-hospital patients | 281 | 24 | 9 | Moderate |
| Wadhwa et al ¹⁰⁶ | US | Cohort | December 2020 | Community residents | 172 | 19 | 12 | Moderate |
| Wi et al ¹⁰⁷ | South Korea | Case series | July 2020 | Community residents | 17 400 | 111 | 25 | High |
| Wood et al ¹⁰⁸ | Indiana | Cross-sectional | August 2020 | Community residents | 511 | 1 | 1 | Low |
| Yamahata et al ¹⁰⁹ | Japan | Cross-sectional | May 2020 | Air or cruise travelers | 3711 | 696 | 410 | Moderate |
| Yassa et al ¹¹⁰ | Turkey | Cohort | July 2020 | Pregnant women | 296 | 23 | 12 | Low |
| Yau et al ¹¹¹ | Canada | Cohort | July 2020 | Health care workers or in-hospital patients | 330 | 22 | 12 | Low |
| Yousaf et al ¹¹² | US | Cohort | July 2020 | Close contact | 195 | 47 | 6 | Low |
| Zhang et al ¹¹³ | China | Case series on transmission | April 2020 | Close contact | 8437 | 25 | 3 | High |
| Zhang et al ¹¹⁴ | China | Cohort | September 2020 | Health care workers or in-hospital patients | 8553 | 235 | 21 | Low |
| Zhao et al ¹¹⁵ | China | Cohort | August 2020 | Health care workers or in-hospital patients | 1060 | 160 | 38 | Low |

Percentage of Asymptomatic Infections Among the Confirmed Population

Among 95 studies, 18 were excluded because that the percentage of asymptomatic infections among the confirmed population was 100%.^{22,30,31,36,39,43,49,56,58,71,77,79-81,87,96,101,108} The remaining 77 studies were included in the meta-analysis for the percentage of asymptomatic infections among the confirmed population,^{12,23-29,32-35,37,38,40-42,44-48,50-55,57,59-70,72-76,78,82-86,88-95,97-100,102-107,109-115} covering 19 884 individuals with confirmed COVID-19, among whom 11 069 had asymptomatic infections. The pooled percentage of asymptomatic infections among the confirmed population was 40.50% (95% CI, 33.50%-47.50%), with high heterogeneity among studies ($I^2 = 99%$; $P < .001$) (eFigure 2 in the Supplement).

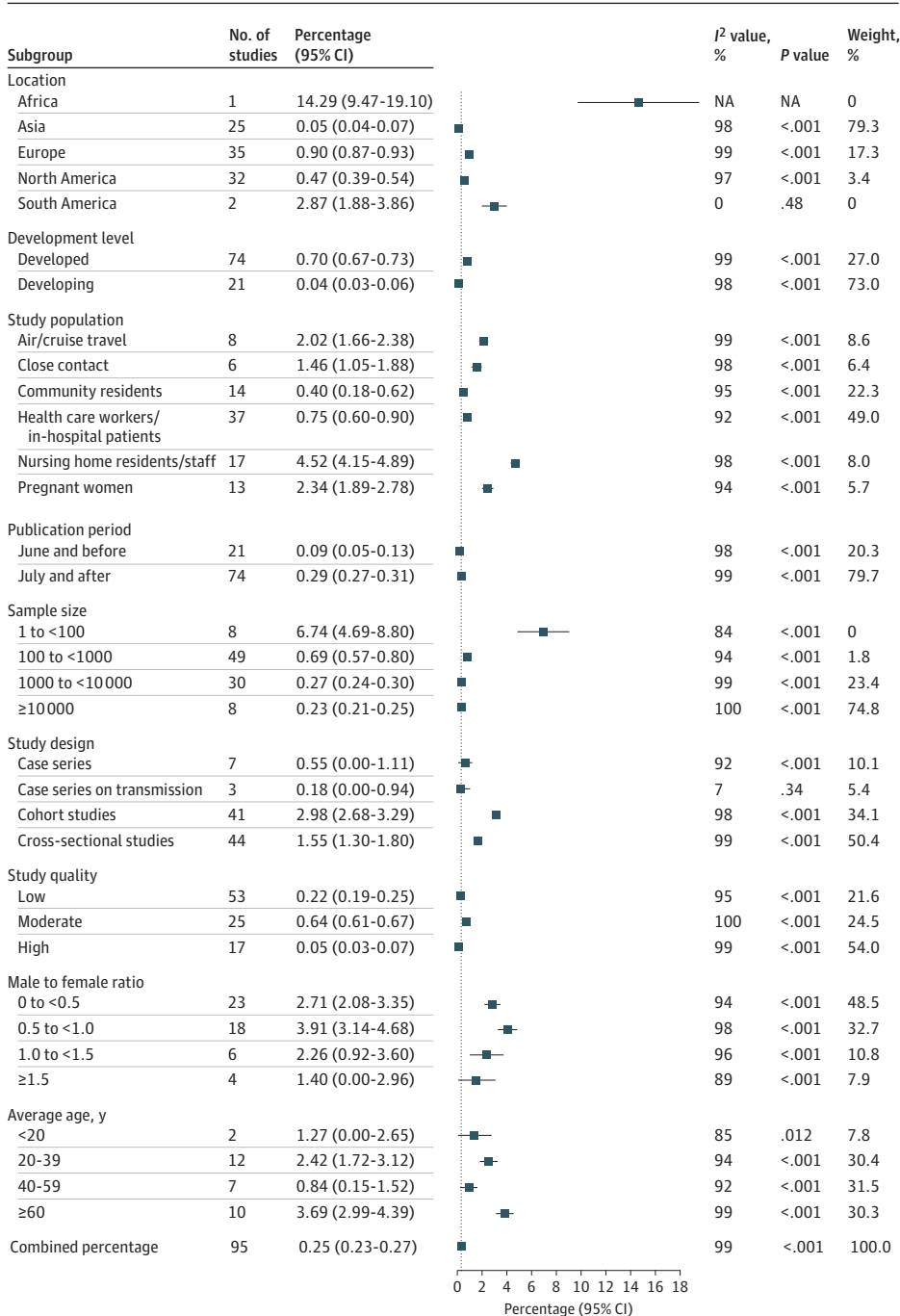
Among the confirmed population, the pooled percentage of asymptomatic infections was 54.11% (95% CI, 39.16%-69.05%) in pregnant women, 52.91% (95% CI, 36.08%-69.73%) in air or cruise travelers, 47.53% (95% CI, 36.36%-58.70%) in nursing home residents or staff, 39.74% (95% CI, 24.50%-54.98%) in community residents, 30.01% (95% CI, 21.13%-38.88%) in health care workers or in-hospital patients, and 26.94% (95% CI, 8.50%-45.38%) in close contacts. The pooled percentage of asymptomatic infections was 46.32% (95% CI, 33.47%-59.16%) in North America, 44.18% (95% CI, 32.87%-55.50%) in Europe, and 27.58% (95% CI, 13.60%-41.57%) in Asia. The pooled percentage was higher in developed countries (43.51% [95% CI, 35.59%-51.44%]), studies published in June or earlier (43.68% [95% CI, 27.87%-59.50%]), studies with sample size of 500 or greater (47.06% [95% CI, 26.22%-67.90%]), and cross-sectional studies (44.47% [95% CI, 33.54%-55.40%]). The pooled percentage was slightly lower for cohort studies (40.96% [95% CI, 31.18%-50.74%]). Among studies with MFR of 1.0 to less than 1.5, the pooled percentage was higher (55.09% [95% CI, 27.64%-82.53%]). The pooled percentage was higher when the mean age of the

study population was younger than 20 years (60.21% [95% CI, 24.51%-95.91%]) or 20 to 39 years (49.49% [95% CI, 33.48%-65.50%]) (Figure 3).

Sensitivity Analysis and Publication Bias

After using the Knapp-Hartung adjustments, the pooled percentage of asymptomatic infections among the tested population was 0.25% (95% CI, 0.11%-0.39%), and the 95% CI of the pooled percentage became slightly larger (eFigure 3 in the Supplement). The percentage of asymptomatic

Figure 2. Percentage of Asymptomatic Infections Among the Tested Population by Subgroups

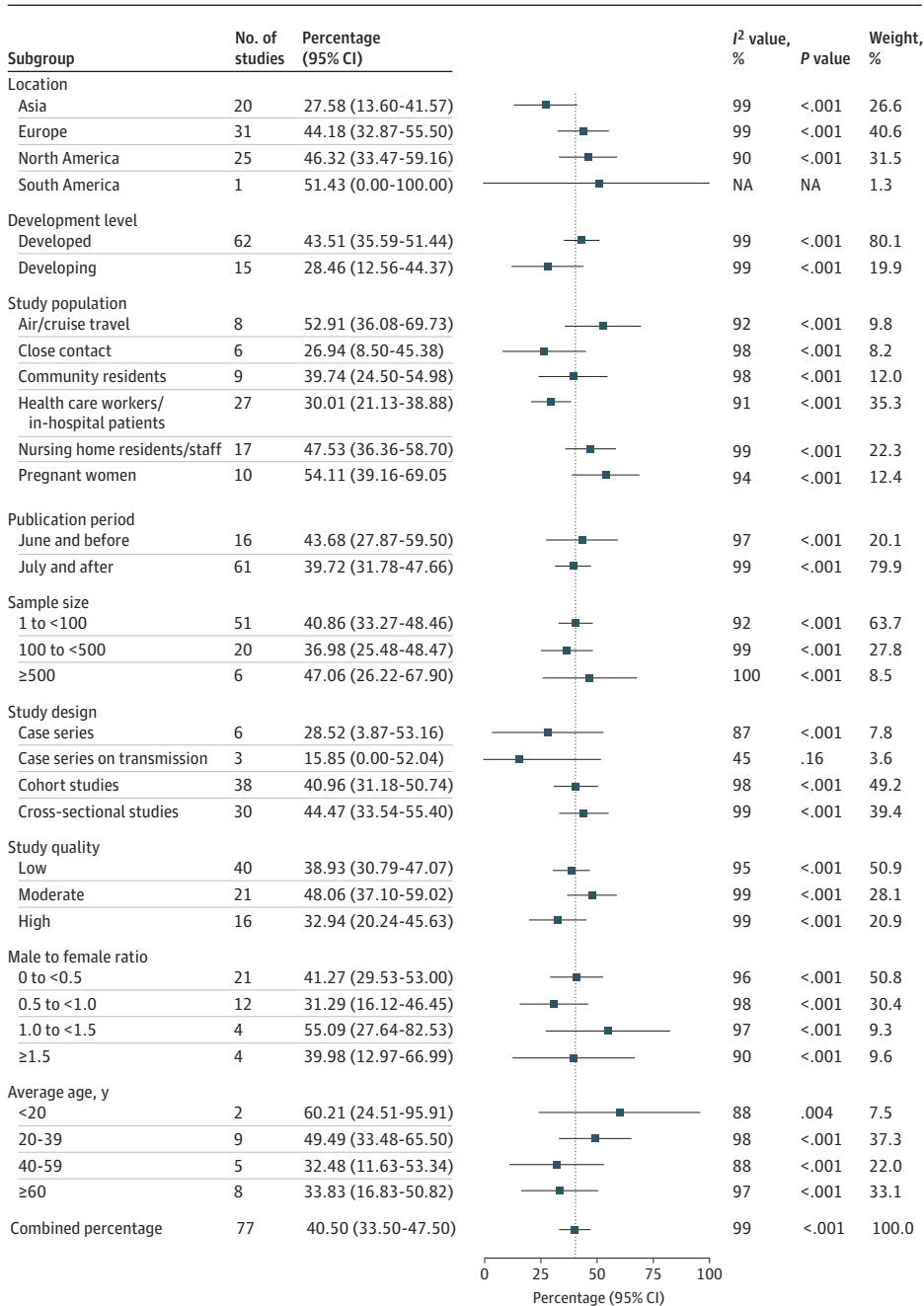


Includes 29 776 306 tested individuals, among whom 11 516 had asymptomatic infections.

infections among the confirmed population was 40.50% (95% CI, 34.94%-46.07%), and the 95% CI of the pooled percentage became slightly narrower (eFigure 4 in the Supplement).

After excluding 3 studies with tested populations of more than 200 000,^{36,52,90} the pooled percentage of asymptomatic infections among the tested population was 1.61% (95% CI, 1.47%-1.76%), which was higher than the original results. The percentage of asymptomatic infections among the confirmed population was 39.37% (95% CI, 33.86%-44.87%), which was slightly lower than the original results. After excluding 53 low-quality studies, the pooled percentage of asymptomatic infections among the tested population was 0.24% (95% CI, 0.23%-0.26%), and the percentage of asymptomatic infections among the confirmed population was 41.71% (95% CI, 31.89%-51.53%). Both percentages were similar to the original results.

Figure 3. Percentage of Asymptomatic Infections Among the Confirmed Population by Subgroups



Includes 19 884 individuals with confirmed COVID-19, among whom 11 069 had asymptomatic infections.

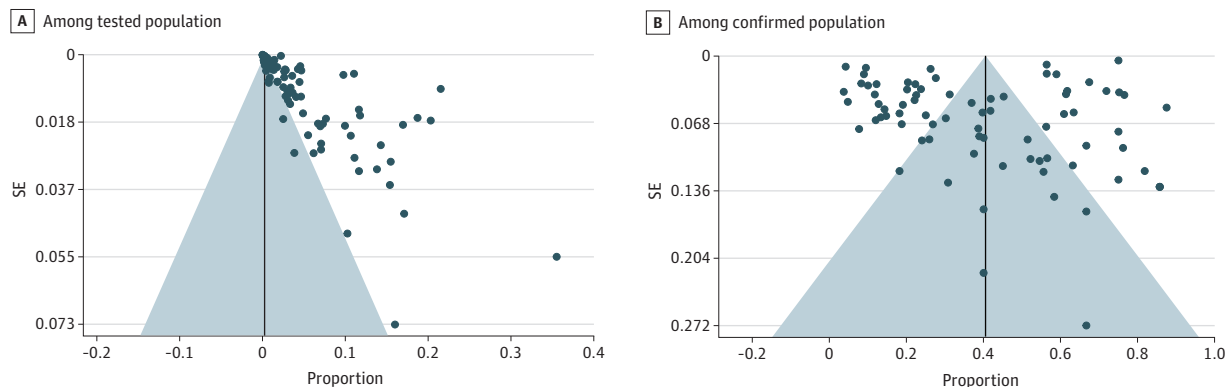
Funnel plots are shown in **Figure 4**. Egger regression tests for the percentage of asymptomatic infections among the tested population ($z = 43.1725$; $P < .001$) and for the percentage of asymptomatic infections among the confirmed population ($z = 2.3846$; $P = .02$) indicated that there might be publication bias.

Discussion

In this meta-analysis, we found that the pooled percentage of asymptomatic infections among the tested population was 0.25% (95% CI, 0.23%-0.27%), and the pooled percentage of asymptomatic infections among the confirmed population was 40.50% (95% CI, 33.50%-47.50%). At present, there are only a few meta-analyses for the percentage of asymptomatic infections among the tested population. We found that the percentage of asymptomatic infections was highest among the tested population in nursing homes and lowest among community residents. Because the percentage of asymptomatic individuals varies as a function of community prevalence, it was not available in all studies. This might be a potential driver of heterogeneity across studies. Furthermore, the percentages of asymptomatic infections among the tested population were different between studies conducted in different locations. Studies in Asia had the lowest percentage, whereas studies in other locations had higher percentages. This lower percentage in Asia might be related to the large city-wide SARS-CoV-2 nucleic acid screening program in China.³⁶ In the sensitivity analyses, we found that the pooled percentage of asymptomatic infections among the tested population was higher than the original results after excluding studies with large sample sizes. This indicated that studies with different sample sizes were very heterogeneous. Owing to severe outcomes among older patients with COVID-19, more studies were conducted among nursing home residents or staff. Thus, asymptomatic individuals were more likely to be tested among this population. As more and more countries conducted expanded screening, studies concerning the percentage of asymptomatic infections among the general population would increase in the future.

In this study, the pooled percentage of asymptomatic infections among the confirmed population was 40.50%. The pooled percentage of asymptomatic infections was 40.96% among cohort studies, which was slightly lower than that among cross-sectional studies (44.47%). The patients who developed symptoms later were mistakenly classified as having asymptomatic infection in cross-sectional studies because the observation time was not long enough.¹⁴ Thus, the percentage of asymptomatic infections was lower in cohort studies, because some patients with presymptomatic findings were identified during follow-up. There were limited case series of great interest in the first months of the pandemic; however, these studies mostly traced and tested limited

Figure 4. Funnel Plots Based on the Percentage of Asymptomatic Infections



Includes 29 776 306 tested individuals, among whom 11 516 had asymptomatic infections and 19 884 individuals with confirmed COVID-19, among whom 11 069 had asymptomatic infections. Funnel plot asymmetry indicated possible publication bias.

contacts, which contributed limited value to the evidence of the percentage of asymptomatic infections.¹⁷ Several meta-analyses concerned the percentage of asymptomatic infections among the confirmed population. Chen et al⁵ conducted a meta-analysis that included 104 published studies and preprints before May 13, 2020. They found that the percentage of asymptomatic individuals among those with COVID-19 was 13.34% (95% CI, 10.86%-16.29%). Unlike our study, Chen et al⁵ searched a Chinese database. Thus, the percentage of Chinese studies was higher in their study than in the present study. He et al¹⁴ searched PubMed and Embase before May 20, 2020, and included 41 published studies. More than 50% of the studies were from China, and the pooled percentage of asymptomatic infection was 15.6% (95% CI, 10.1%-23.0%). In our study, we only included published studies. The percentage of countries excluding China was higher than the previous meta-analysis.¹⁴ This might be the reason for the higher percentage of asymptomatic infections found in our study compared with studies conducted by Chen et al⁵ and He et al.¹⁴ Another meta-analysis conducted by Yanes-Lane et al¹⁷ included published studies and preprints before June 22, 2020. After quality assessment, 28 studies were of high or moderate quality and were included in the meta-analysis. The percentage of asymptomatic infection among persons with confirmed COVID-19 varied among different study populations, with the highest observed in obstetric patients (95% [95% CI, 45%-100%]).

In our study, the percentage of asymptomatic infections among the confirmed population was 54.11% in pregnant women and 52.91% in air or cruise travelers. The percentage was 47.53% in nursing home residents or staff. This finding of a high percentage of asymptomatic infections among air or cruise travelers suggests that screening and quarantine on airport arrival is important for reducing community transmissions, especially in countries without local transmission.^{3,25} In addition, we found that the percentage of asymptomatic infections among the tested population was relatively low among community residents. However, the percentage of asymptomatic infection among confirmed individuals was 39.74% in communities. These findings suggest that asymptomatic infections might contribute to the transmission of SARS-CoV-2 within the community. To prevent further transmission in communities, asymptomatic individuals among the general population should be tested. If resources are limited, workers in specific industries such as air transportation should be routinely tested. In addition, we found that approximately one-third of individuals with confirmed COVID-19 were asymptomatic among health care workers or in-hospital patients. Because asymptomatic health care workers might contribute to disease spread in and out of hospitals, surveillance of asymptomatic individuals is important for infection control and transmission reduction in health care settings and community.^{116,117} Meanwhile, hand hygiene and personal protective equipment were necessary for hospital visitors.¹¹⁷ A previous study showed that most asymptomatic patients belong to younger groups,³ which was consistent with the findings of our study. The percentage of asymptomatic infections was higher among groups younger than 39 years than in other age groups, possibly because the young adults were more likely to show only mild or moderate clinical symptoms.⁵ This indicated that young adults who often presented mild or no symptoms were a potential source of transmission in the community.

In the meta-analysis, we included studies published before February 3, 2021, providing the most updated pooled percentage of asymptomatic infections among tested and confirmed populations. We included countries in Africa, Asia, Europe, North America, and South America and estimated the percentage of asymptomatic infections for different populations. Our results could raise awareness among the public and policy makers and provide evidence for prevention strategies.

Limitations

This study has several limitations. First, we did not include preprints and therefore may have missed some relevant studies; however, we thought that the results of published studies were more reliable. Second, some relevant articles written in Chinese may not be included because we did not search Chinese literature databases such as China National Knowledge Infrastructure. Third, most studies did not follow up to identify presymptomatic and covert infections. Future studies should evaluate

the percentage of these 2 types of asymptomatic infection among the confirmed population. Fourth, most studies were conducted in a specific population; thus, our findings might not be generalizable to the general population. Fifth, the heterogeneity between studies was high, which might be related to different study location, period, population, and sample size. Sixth, the Egger regression test suggested potential publication bias in this study. Because studies that did not detect asymptomatic infections were less likely to be published, our pooled percentage of asymptomatic infections might be overestimated.

Conclusions

In this systematic review and meta-analysis, we found that the pooled percentage of asymptomatic SARS-CoV-2 infections among the tested population was 0.25%. Among the confirmed population, 40.50% of individuals had asymptomatic infections. The high percentage of asymptomatic infections highlights the potential transmission risk of asymptomatic infections in communities. Screening for asymptomatic infection is required, especially for countries and regions that have successfully controlled SARS-CoV-2. Asymptomatic infections should be under management similar to that for confirmed infections, including isolating and contact tracing.

ARTICLE INFORMATION

Accepted for Publication: October 8, 2021.

Published: December 14, 2021. doi:[10.1001/jamanetworkopen.2021.37257](https://doi.org/10.1001/jamanetworkopen.2021.37257)

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Corresponding Author: Min Liu, PhD, Department of Epidemiology and Biostatistics, School of Public Health, Peking University, 38 Xueyuan Rd, Haidian District, Beijing 100191, China (liumin@bjmu.edu.cn).

Author Affiliations: Department of Epidemiology and Biostatistics, School of Public Health, Peking University, Beijing, China (Ma, J. Liu, Q. Liu, Kang, Jing, Wu, M. Liu); School of Health Humanities, Peking University, Beijing, China (R. Liu).

Author Contributions: Dr M. Liu had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs Ma and J. Liu contributed equally to this study and are co-first authors.

Concept and design: Ma, J. Liu, Jing, M. Liu.

Acquisition, analysis, or interpretation of data: Ma, Q. Liu, Kang, R. Liu, Wu, M. Liu.

Drafting of the manuscript: Ma, Q. Liu, Kang, R. Liu.

Critical revision of the manuscript for important intellectual content: J. Liu, Jing, Wu, M. Liu.

Statistical analysis: Ma, J. Liu, Q. Liu, Jing.

Obtained funding: J. Liu, M. Liu.

Supervision: M. Liu.

Conflict of Interest Disclosures: None reported.

Funding/Support: This work was supported by grants 71934002, 71874003, and 72122001 from the National Natural Science Foundation of China.

Role of the Funder/Sponsor: The sponsor had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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SUPPLEMENT.

eMethods 1. Search Strategies

eMethods 2. Study Quality Assessments

eFigure 1. Percentage of Asymptomatic Cases Among the Tested Population

eFigure 2. Percentage of Asymptomatic Cases Among the Confirmed Population

eFigure 3. Percentage of Asymptomatic Cases Among the Tested Population by Subgroups, Using the Knapp-Hartung Adjustments

eFigure 4. Percentage of Asymptomatic Cases Among the Confirmed Population by Subgroups, Using the Knapp-Hartung Adjustments