The Rate of Asymptomatic COVID-19 Infection: A Systematic Review and Meta-analysis Including 12,713 Infections from 136 Studies

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Abstract

Background: Asymptomatic infection of SARS-CoV-2 may lead to silent community transmission and compromise pandemic control measures of COVID-19. We aimed to estimate the rate of asymptomatic COVID-19 infection from published studies, and compare this rate among different patient groups.

Methods: The electronic databases including Medline, Embase, PubMed, and three Chinese electronic databases (The Chinese National Knowledge Infrastructure (CNKI), WanFang Data, and VIP) were searched. Studies with sample size (or number of subjects) not less than 5 were included. The STATA command '*Metaprop*' was implemented to conduct meta-analysis for the pooled rate estimates of asymptomatic infections with exact binomial and score test-based 95% confidence intervals (CIs).

Results: A total of 12,713 COVID-19 patients in 136 studies were included in the meta-analysis, including 2,785 asymptomatic infections. The overall rate of asymptomatic infection was 15.1% (95% CI: 12.0%-18.4%). Subgroup analysis showed that the rate was significantly higher in pregnant women (36.3%, 95% CI: 15.7%-59.6%), children (29.4%, 17.4%-42.9%), and studies for screening settings (25.3%, 15.4%-36.5%) conducted on or after 01 March 2020 (27.8%, 15.7%-41.7%). In terms of geographical regions, the rate was the highest in Asia (excluding China) (27.4%, 14.3%-42.6%), followed by Europe (22.7%, 6.3%-44.9%), the US (15.9%, 8.9%-24.3%), and China (13.1%, 10.2%-16.3%).

Conclusions: High proportion of asymptomatic infection were observed in pregnant women, children, European residents, screening programmes, and in studies conducted in and after March 2020. Our findings help inform the true burden of COVID-19 among different groups of cases, and provide information on cost-effective strategies of identifying and tracing asymptomatic infections.

Background

In 2019, a cluster of severe pneumonia cases of unknown type were reported in Wuhan, China (1). Later coined as the coronavirus disease 2019 (COVID-19), it rapidly resulted in large-scale outbreaks across many regions. On 30 January 2020, the World Health Organization (WHO) declared the COVID-19 as a public health emergency of international concern (2), and further defined it as a pandemic on 11 March 2020. As of 2 September 2020, a cumulative total of 25,937,361 COVID-19 cases have been confirmed globally, with 861,910 associated deaths.

The pathogen of COVID-19, i.e., severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is highly contagious, and could be transmitted from human to human (1, 3). The viral load in an asymptomatic patient has been found to be similar to that in symptomatic patients in a study of nine patients (4), and this observation was later confirmed in a study involving large samples (5). The early peaking of SARS-CoV-2 viral load during the pre-symptomatic phase may cause silent community outbreaks (6). Further investigations also found that the asymptomatic infections may carry SARS-CoV-2 for more than 1 month, indicating the long lasting risk of secondary infection (7–11). Several similar definitions of 'asymptomatic case' were noted in previous studies (12). We followed the official definition from the

State Council of China and the World Health Organization (WHO) (13, 14), and defined 'asymptomatic case' as individuals who 1) have no clinical manifestations of COVID-19, such as fever, cough, sore throat, and other self-perceived or clinically identifiable symptoms and signs; 2) have positive result of SARS-CoV-2 pathogen test; and 3) does not develop symptoms until the end of hospital admission or follow-up observations. Asymptomatic COVID-19 infection rate, or asymptomatic ratio, is calculated as the proportion of asymptomatic cases among all COVID-19 infections.

The significance of asymptomatic infection in COVID-19 pandemic has been widely discussed in previous studies. On one hand, asymptomatic cases pose threat to groups at risk (e.g. elderly and groups with health conditions). On the other hand, asymptomatic infections cannot be ascertained without diagnosis by laboratory testing (15), and they are less easily recognized in the community. However, undetected carriers tended to retain normal social and travel activities (16), resulting in high risk of latent transmission in the community (17). Mass screening and isolation of both cases and close contacts are effective methods for halting transmission in community-based settings (18), yet bear substantial social and economic costs. Thus, detecting and managing asymptomatic individuals represent one of the crucial measures in controlling the epidemic spread (19, 20).

Determining the rate of asymptomatic infection is important as it may deepen the understanding of the real reproductive number (R_0), as well as the true incidence and mortality rate of COVID-19. The rate may also function as an essential epidemiological parameter to inform disease combating policies, including the density and range of screening, patient isolation as well as early intervention (20). Nevertheless, the significance of the invisibly infected person as the source of infection depends on its distribution in the population, and the amount and duration of the virus excreted (21). The reported proportions of asymptomatic individuals in existing literature varied a lot (20), depending on their research settings (e.g. geographical region, screening vs. non-screening studies), demographic characteristics (e.g. age groups, pregnant women, children), and other latent factors. The present study performed a systematic review and meta-analysis to estimate the asymptomatic infection rate based on published studies, and compare the rate among different patient groups as well as study settings.

Methods

Searching strategy

The Medline, Embase, PubMed, and three Chinese electronic databases (the Chinese National Knowledge Infrastructure [CNKI], WanFang Data, and VIP) were searched from 1 November 2019 to 10 July 2020 for studies reporting the rate of asymptomatic COVID-19 infection. This systematic review and meta-analysis was conducted according to the standards strictly following the '*Preferred Reporting Items for Systematic reviews and Meta-Analyses*' (PRISMA) guideline (22). The searching details were presented in the Additional file 1. Meanwhile, highly relevant references were also searched by reviewing the reference list of the included articles All manuscripts were imported into the Endnote software (version X8, Thomson Reuters, Carlsbad, California) and duplicate studies were removed.

Literature screening and selection criteria

Two reviewers (XC and ZH) determined the eligible studies independently. Consensus was reached by referral to a third reviewer (JW) when there was disagreement. All studies were screened by title and abstract first, followed by full texts if the study meets the inclusion criteria, which consist of:

- inclusion criterion #1: the studying subjects were diagnosed with SARS-CoV-2 infection;
- inclusion criterion #2: the study was designed as an observational study; and
- inclusion criterion #3: the numbers of asymptomatic and symptomatic COVID-19 patients were explicitly and exactly reported.

The literature screening was conducted without language or region restriction. The exclusion criteria are as follows. They included

- exclusion criterion #1: study that included patients without virological evidence of SARS-CoV-2 infection;
- exclusion criterion #2: study which did not investigate the distribution of asymptomatic COVID-19 infections among all subjects;
- exclusion criterion #3: study that is not classified as original research, such as reviews, comments, case report; and
- exclusion criterion #4: study has an overall sample size of less than 5.

For studies that analyzed the same group of subjects more than once, only those with the most updated and detailed information were included for further analysis.

Data extraction and subgrouping schemes

For eligible articles, two types of the information were extracted by the two reviewers (XC and ZH) independently. For each study, we include

- information type #1: the basic information of the individual studies that contains the name of the first author, investigation period, geographical region, and the study setting (screening and non-screening); and
- information type #2: the characteristics of subjects including age statistics, sex distribution, sample size, the number of COVID-19 infections, the number of asymptomatic COVID-19 infections, and the number of subsequent clinically detectable symptoms among symptomatic COVID-19 cases.

To ensure the accuracy of data, cross-checking was conducted after extraction of the preliminary information. Disagreements were resolved through consensus or by referral to the third reviewer (JW).

To explore the source of heterogeneity among the included studies, several subgroup analyses were performed according to the study design and characteristics of subjects in each study. First, we identified

three groups based on the subjects' demographical features. They included 'children' groups consisting of subjects less than 18 years old; 'pregnant women' groups involving expectant mothers as subjects; and the 'general population' group. Second, three age groups were identified according to the subjects' mean or median age: $\leq$ 18, from 19 to 45, and > 45 years, respectively. The selection of mean or median age followed the statistics reported in each study. Third, studies were categorized into 'screening' or 'non-screening' types, identified by examining whether all subjects in each study were previously diagnosed with COVID-19. Forth, we separated studies based on subjects from different geographical regions including China, Asia (excluding China), the US and Europe. Last, subgroup analysis was performed by study period, during which the subjects were tested for COVID-19, including 'before 01 March 2020' or '01 March 2020 and afterwards'.

Quality assessment

The quality of each included study was assessed by two researchers (XC and ZH) independently using the quality of cross-sectional studies (AXIS) scale (23). There are five components including 20 questions in the AXIS scale. Seven questions measure the quality of reporting; another seven questions measure the quality of study design, and six questions measure the possible introduction of biases in each study.

Statistical analysis

Accounting for all included studies, the pooled estimates of the asymptomatic rates were generated with exact binomial-distributed likelihood framework and score test-based 95% confidence intervals (CIs) (1). The STATA command "*metaprop*" was adopted to conduct meta-analysis. Heterogeneity across the studies was examined by the I^2 statistic, measuring the proportion of total variation contributed by between-study variation. The I^2 values < 25%, ranging from 25–75%, and > 75% correspond to the thresholds for three ordinal levels of heterogeneity including low, moderate, and high, respectively (24).

Univariate and multivariate meta-regression analysis was performed to identify any potential effects of modifiers or confounders on the estimated rate. We examined the effects of the covariates including study population, age-specific proportion, screening/non-screening study, geographical region, and time trend in multivariate analysis. Sensitivity analysis was conducted by omitting one study at a time, generating the pooled estimates and comparing with the original estimates. Potential publication bias was examined by Egger's test and visualized using a funnel plot. If the tests indicated potential publication bias, the Trim and Fill's method, which is based on a modified funnel plot, would be adopted to adjust the small-study effect (25).

All analyses were performed using STATA statistical software (version 14.0, Stata, College Station, Texas, USA). The figures were generated using R software (version 3.6.3) with the '*forestplot*' package.

Results

Characteristics of studies and subjects

4,243 citations were identified by the literature search, of which 362 were from MEDLINE, 573 were from PubMed, 955 were from Embase, 1,106 were from CNKI (Chinese), 1,010 were from WanFang (Chinese), and 237 were from VIP (Chinese) (Fig. 1). There were 3,268 citations after removal of duplicates. We retrieved 382 full-text articles assessed for eligibility after 686 citations were excluded during title or abstract screening with pre-determined criteria. We excluded 245 articles that were reviews, comments, and editorials; case reports; did not report sufficient information to calculate the asymptomatic rate; presented irrelevant topics; or consisted of duplicate data source. Finally, there were 136 articles included in the meta-analysis.

The basic characteristics of the included studies are shown in **Additional file 2** including cities, countries and study periods in which the COVID-19 patients were recruited; the number of test-positive and asymptomatic patients; the number of presymptomatic infection in patients if available; and the travel history and demographics of each patient. Approximately 80.1% (109 out of 136) of all included studies were conducted in China, 4.4% in the US, 2.9% in Japan, and 2.2% in Korea. Among 136 studies, 89.0% were performed among the general population, 7.4% in children and 3.7% in pregnant women, respectively.

Quality scores of AXIS for the included studies ranged between 11 and 19 points, with 69 studies meeting the criteria of having high quality (≥ 16 points). Overall, 97.1% (132 out of 136) of all studies met the criteria for both reporting and quality design, and the risk factors and outcome variables were appropriate for the studies. In all studies, the methods were clearly defined so that those studies could be repeated, and the presentation of results met the analysis descriptions in the methods with internal consistency (**Additional file 3**).

Asymptomatic ratio estimates

A total of 12,713 COVID-19 patients from 136 studies were finally included in the meta-analysis (Fig. 2), including 2,889 asymptomatic infections at the time of diagnosis. The overall rate of asymptomatic infections was estimated at 16.8% (95% CI: 13.7%-20.1%). The I^2 equaled to 96.0%, indicating a high heterogeneity among the studies. Of the 2,889 asymptomatic infections, 104 (3.6%) developed symptoms after admission. After excluding these pre-symptomatic observations, the pooled rate was 15.1% (95% CI: 12.0%-18.4%) at a I^2 of 96.2%.

In subgroup analysis, we found that pregnant women (36.3%, 95% CI: 15.7%-59.7%; $I^2 = 79.6\%$) had a significantly higher asymptomatic infection rate than children (29.4%, 95% CI: 17.4%-42.9%; $I^2 = 87.2\%$), whereas the general population had the lowest asymptomatic rate (13.5%, 95% CI: 10.4%-16.7%; $I^2 = 96.4\%$) (p-value < 0.001). Regarding age-specific proportion, patients aged ≤ 18 years (22.9%, 95% CI: 14.6%-32.1%; $I^2 = 66.2\%$) had a significantly higher prevalence of asymptomatic cases than adults aged 19–45 years (16.5%, 95% CI: 10.8%-22.9%; $I^2 = 94.0\%$) or > 45 years (9.3%, 95% CI: 5.8%-13.4%; $I^2 = 93.5\%$) (p-value < 0.001).

The asymptomatic infection rate was 25.3% (95% CI: 15.4%-36.5%; I^2 = 97.3%) among studies for screening settings, which is almost twice of that among studies for non-screening settings (12.9%, 95% CI: 10.3%-15.8%; I^2 = 94.0%) (p-value < 0.001). Significantly different asymptomatic rates were observed in different geographical regions (p-value < 0.001) - the rate was highest in Asia (excluding China) (27.4%, 95% CI: 14.3%-42.6%; I^2 = 92.6%), followed by Europe (22.7%, 95% CI: 6.3%-44.9%; I^2 = 98.1%), and the US (15.9%, 95% CI: 8.9%-24.3%; I^2 = 94.9%). China was estimated to have the lowest rate of asymptomatic infection (13.1%, 95% CI: 10.2%-16.3%; I^2 = 93.7%). For subgroup analysis by time period, we noted that studies conducted before 01 March 2020 reported a pooled asymptomatic infection rate of 11.2% (95% CI: 7.5%-15.3%; I^2 = 95.0%), while the rate increased sharply to 27.8% (95% CI: 15.7%-41.7%; I^2 = 98.4%) among studies conducted after 01 March 2020.

All subgroup analysis results were shown in Fig. 3.

We performed both univariate and multivariate meta-regression analysis to investigate study-level factors that may contribute to the heterogeneity among studies and might have influenced our estimations of the asymptomatic infection rate. The results (Table 1) presented that the estimation on rate of asymptomatic infection was not significantly altered by population groups (p-values range from 0.227 to 0.457) or age groups (p-values range from 0.478 to 0.992). Being ‘non-screening’ studies where all subjects were diagnosed with COVID-19 would marginally alter the estimation (p-value = 0.113). Geographical location (studies in Asia excluding China) (p-value = 0.019) and study period (01 March 2020 afterwards; p-value = 0.005) were significant sources of heterogeneity.

Table 1
Results of Univariate and Multivariate Meta-regression Analysis

Variable	Univariate Regression Analysis				Multivariate Regression Analysis		
	No. of Studies (%)	Crude Meta-RR	95% CI	*p*-value	Adjusted Meta-RR	95% CI	*p*-value
Patient Group							
Children	10 (7.35%)	1 (Reference)	1 (Reference)		1 (Reference)	1 (Reference)	
Pregnant	5 (3.68%)	1.13	(0.85–1.48)	0.398	1.12	(0.82–1.53)	0.457
General population	121 (89.97%)	0.88	(0.76–1.01)	0.075	0.89	(0.73–1.08)	0.227
Age							
≤ 18y	9 (6.61%)	1 (Reference)	1 (Reference)		1 (Reference)	1 (Reference)	
19-45y	49 (36.03%)	0.95	(0.79–1.13)	0.565	1.05	(0.82–1.34)	0.712
> 45y	49 (36.03%)	0.88	(0.74–1.05)	0.165	1.00	(0.78–1.27)	0.992
NM	29 (21.32%)	0.98	(0.81–1.17)	0.798	1.09	(0.86–1.37)	0.478
Screening							
Non-screening studies	112 (82.35%)	1 (Reference)	1 (Reference)		1 (Reference)	1 (Reference)	
Screening studies	24 (17.65%)	1.14	(1.05–1.25)	**0.003**	1.08	(0.98–1.20)	0.113
Region							
US	6 (4.51%)	1 (Reference)	1 (Reference)		1 (Reference)	1 (Reference)	
China	109 (81.95%)	0.96	(0.83–1.11)	0.569	1.12	(0.96–1.31)	0.159
Europe	9 (6.77%)	1.07	(0.89–1.29)	0.468	1.04	(0.87–1.24)	0.645
Asia (exclude China)	9 (6.77%)	1.12	(0.92–1.36)	0.274	1.26	(1.04–1.53)	**0.019**

Variable	Univariate Regression Analysis				Multivariate Regression Analysis		
Time Trend							
Before 01 March 2020	85 (62.50%)	1 (Reference)	1 (Reference)		1 (Reference)	1 (Reference)	
01 March 2020 afterwards	10 (7.35%)	1.23	(1.09–1.39)	**0.001**	1.27	(1.08–1.50)	**0.005**
NM	41 (30.15%)	1.07	(1.00-1.16)	0.039	1.07	(1.00-1.15)	0.061
NM, not mentioned.							

We found no evidence of publication bias among studies by Egger's test with *p*-value = 0.415. Sensitivity analysis showed that it was unlikely that any individual study significantly influenced the pooled estimates, demonstrating the robustness and reliability of our estimates (**Additional file 4)**.

Discussion

Our meta-analysis of 12,713 patients in 136 studies performed in 15 countries provides an up-to-date as well as comprehensive overview of asymptomatic infection rate of COVID-19. We also estimated the statistics by different study settings and patients' demographic factors. We found a higher asymptomatic ratio in European countries, in studies on screening settings, and among pregnant women as well as younger populations. The estimated rate in our study (15.1%) is half the size of a previous estimate (33.0%) using binomial distribution (26), yet is consistent with the estimation using Hamiltonian Monte Carlo (HMC) algorithm (27). Regarding real-world evidence, our estimation is consistent with a meta-analysis of 41 studies in May 2020, which also noted an asymptomatic infection rate of approximately 15%, with a higher rate among pregnant women and children (28). The findings are very similar with that of the present study. However, our study included 100 more articles, resulting in a more precise estimation with significantly narrower confidence interval. With a larger dataset, we conducted more subgroup analysis which resulted in more implications. First, while China and the US were having a similar asymptomatic infection rates, the rate is two times higher in European countries as well as Asian countries (excluding China). Second, the proportion of asymptomatic carriers was nearly doubled in screening studies than that in non-screening studies. Third, asymptomatic infection rate was significantly higher in studies conducted in or after 01 March 2020 than those conducted beforehand.

In the subgroup analysis, we noted a large variety of asymptomatic rates among different populations. For instance, younger people tended to have a significantly higher rate. These findings are consistent with that from previous publications (29), older age is a risk factor for complications and severe symptoms after infection (30). Many pre-existing chronic conditions are also identified as risk factors for more severe symptoms, while the conditions are less likely to be observed among the younger people (31).

Infection control measures may be targeted on the early detection and isolation of asymptomatic youth, as the young asymptomatic carriers are of higher probability to bring in community transmission due to their more socially active lifestyle habits with more frequent travelling than people in other age groups (32).

We also noted that the asymptomatic infection rate for pregnant women (36.3%) is almost three times that for the general population (13.5%). Previous publication on pregnant women and COVID-19 is very limited. Case reports from the New York hospital reported a similarly high rate (14 women, 32.6%) at presentation, yet 71.4% (10 women) of the asymptomatic mothers developed symptoms during their hospitalization and postpartum course (33). Therefore, the high proportion of asymptomatic infections estimated by our study may include both pre-symptomatic and asymptomatic cases, due to a high proportion of pregnant women undergoing COVID-19 screening at inpatient admission. More follow-up studies among the pregnant women are needed before drawing further conclusions. Nevertheless, undetected asymptomatic pregnant women may lead to more severe consequences. Several studies have reported a high risk of complications (such as respiratory distress) requiring supportive care during COVID-19 patients' delivery, resulting in higher risk of transmission from the mothers to healthcare professionals. Without early detection and proper preventive measures, the delivery of asymptomatic patients brings extra risks to nosocomial infection, and may also result in droplet transmission among the women, kids, as well as other family members (33). Importantly, the data suggest that the severity and mortality risk of hospital transmission may be greater than that of community-acquired COVID-19 (34).

We compared the asymptomatic infection rate in China, in Asia (excluding China), in the US, and in Europe. Previous meta-analysis indicated no significant difference in the proportion of asymptomatic infection between studies conducted in China or other countries (35). On the contrary, our results showed that the rates in Europe (22.7%) and Asia (excluding China) (27.4%) were almost twice than that in China (13.1%) and the US (15.9%). For China, the rate is consistent with a previous meta-analysis (15.6%) (36), as well as the latest government release on Wuhan population nucleic acid testing (14.7%) (37). The changing rate of asymptomatic infection in Hong Kong also confirmed our findings - in the first phase of the pandemic, the infected cases were dominated by imported ones from mainland China, and the asymptomatic infection rate was around 16% (28); whereas in the second and third waves, the infections were mainly imported from Europe and South-East Asian countries, giving a significantly higher rate (23%) (38). However, the smaller sample size for Europe and Asia (excluding China) led to wider confidence intervals for the two regions.

We noted that the asymptomatic infection rate was nearly doubled in screening studies than that in non-screening studies. If we consider the ate as a constant, the higher asymptomatic infection rate estimates were likely due to higher probabilities of ascertaining asymptomatic COVID-19 infections in the community with screening implemented. This implies the importance of mass screening in detecting the infections, which is of importance in community infection control. Increasing the accessibility and

affordability of community testing could be an important surveillance strategy for early containment of diagnosed cases (16).

We also found that the pooled asymptomatic infection rate increased from 11.2% (95% CI: 7.5%-15.3%) for studies conducted before 01 March 2020, to 27.8% (95% CI: 15.7%-41.7%) for studies conducted in 01 March 2020 or afterwards, although the 95% CI is larger in the latter time period. This timeline is highly consistent with a previous study using the publicly released from the Centre for Health Protection in Hong Kong (39). Similarly, the COVID-19 epidemic in the Diamond Princess cruise ship also demonstrated an increasing trend of asymptomatic infection rate during the course of the epidemic, which was estimated at 16.1%(35/218) before 13 February, and steadily increased to 50.5% (320/634) as of 20 February (27, 40). The increased rate may be due to overlooking of asymptomatic, especially pre-symptomatic cases at the early stage of the pandemic, when medical resources were targeted to patients with severe symptoms. Later, with increased public awareness and test accessibility, more COVID-19 infected individuals without symptoms were detected, while more and more studies reported the proportion of asymptomatic patients. In this context, future studies may explore whether the proportion of COVID-19 patients with mild or no symptoms is increasing, especially when considering the SARS-CoV-2 variant with D replaced by G at the 614-th codon in the Spike protein which dominated the pandemic since late February 2020 (41–44).

This study has limitations. First, our pooled asymptomatic infection rates were found to have a high level of heterogeneity (I^2 = 96.2%). This could be attributed to the difficulties in generating the exact number of infections and asymptomatic cases during an outbreak. Different studies reported at different time periods, regions and populations may result in diverse prevalence (45). We conducted subgroup analysis and meta-regression to figure out the source of heterogeneity. This high level may be due to some unobserved factors which have not be included in the original studies, such as changing pandemic control measures in some countries; the diverse definition of asymptomatic infection, varying practices of surveillance and ascertainment of asymptomatic infection; as well as meteorological disparities across time and regions. Nevertheless, previous studies indicated that any amount of heterogeneity is acceptable if both accurate data and predefined eligibility criteria were provided (46, 47). Second, although we applied a comprehensive searching strategy for the literature, 80% of the selected articles and (50,973/55,951 = 91.1%) of the sampled individuals in our analysis are from China (35,003 individuals) and the US (15,970 individuals). Subgroup analysis was conducted to compare the ratio in different geographical regions, yet there are very few studies performed in Australia and Africa by the end of July 2020. Third, a symptomatic COVID-19 case might be mis-classified as 'asymptomatic' during the incubation period. Although we excluded 104 (3.6%) subjects who developed symptoms in the follow-up period, most studies are cross-sectional without follow-up data, while other individuals may not have completed observations for the whole incubation period. This may result in a certain degree of overestimation on the asymptomatic infection rate, yet we consider the impact from this phenomenon as minor owing to our relatively long study period. With additional information of the exposure and reporting

dates of each case, we remark our estimation can be extended to a right censoring version to further address some potential bias in the existing frameworks (20).

Conclusions

We estimated the asymptomatic infection rate of 15.1% among COVID-19 infections. We reported that pregnant women, children, European residents, screening programmes, and studies conducted after 01 March 2020 had higher asymptomatic infection rates. Our findings provide further insights on the distribution of asymptomatic COVID-19 infections in different groups of individuals, which bear significance on public health policies that aim to achieve early identification and more stringent containment of the pandemic.

List Of Abbreviations

CNKI	The Chinese National Knowledge Infrastructure
95% CIs	95% confidence intervals
COVID-19	coronavirus disease 2019
WHO	World Health Organization
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
HMC	Hamiltonian Monte Carlo

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Competing interests

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Author’s contributions

XC and ZH designed the study and searched the literature. XC, ZH, and JW extracted the data and evaluated the quality. XC conducted the statistical analysis. XC, ZH, and JW wrote the full manuscript. SZ, MSCW, MKCC, DH, and JL provided critical revision of the manuscript for important intellectual content. All authors discussed the results, and approved the final version of the manuscript for publication.

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Figures

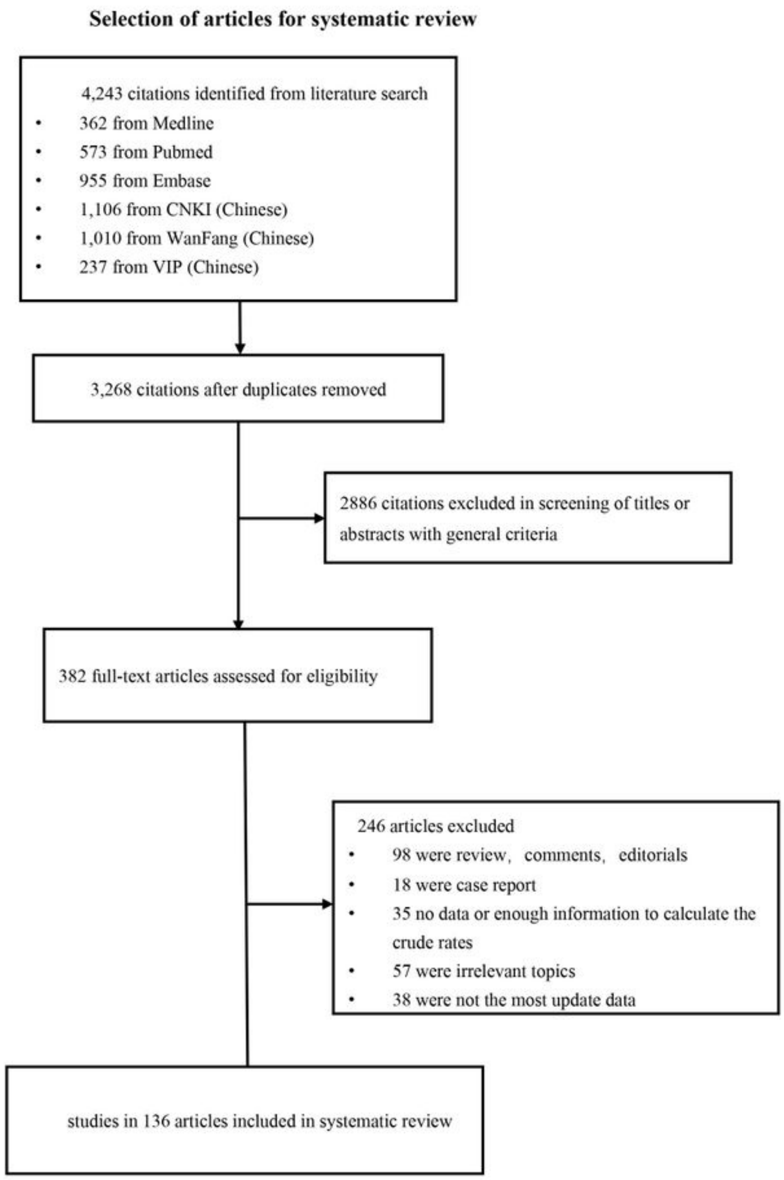

Figure 1

Selection of articles for systematic review

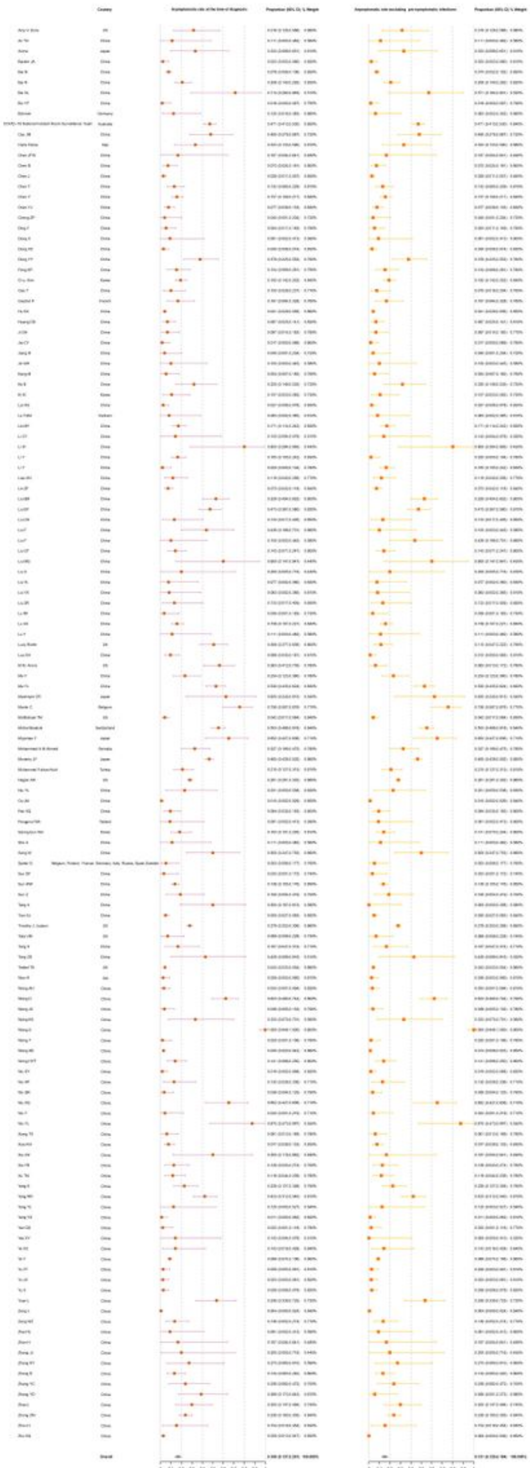

Figure 2

Meta-analysis of the asymptomatic ratio among COVID-19 patients (including and excluding pre-symptomatic infections)

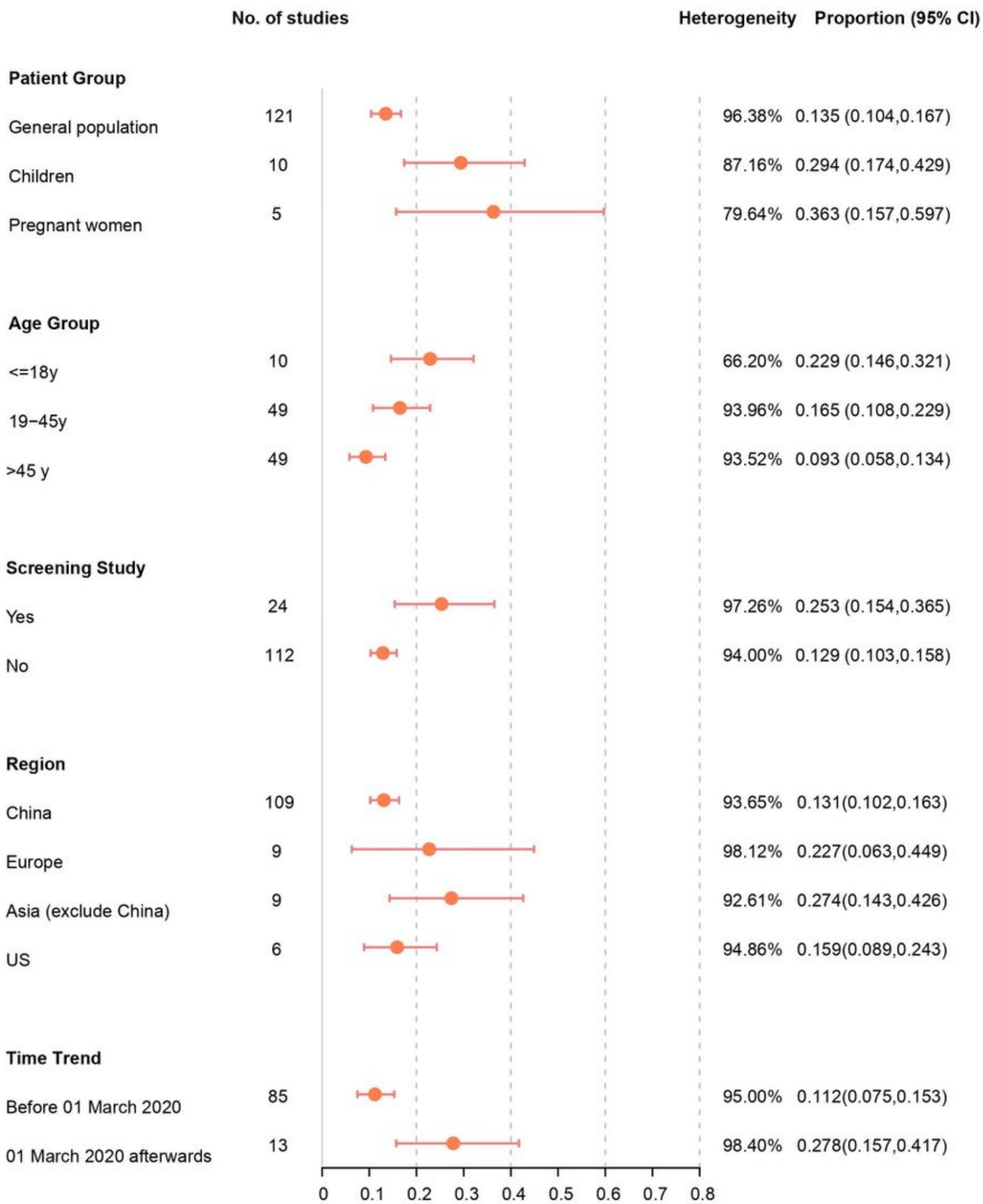

Figure 3

Asymptomatic ratio among COVID-19 patients by patient group, age group, screening study, region, and time trend

Supplementary Files

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- Additionalfiles2012101.doc