



SYSTEMATIC REVIEW

# A rapid review and meta-analysis of the asymptomatic proportion of PCR-confirmed SARS-CoV-2 infections in community settings [version 1; peer review: awaiting peer review]

Sarah Beale <sup>1,2</sup>, Andrew Hayward <sup>2</sup>, Laura Shallcross <sup>1</sup>,  
Robert W. Aldridge <sup>1</sup>, Ellen Fragaszy <sup>1,3</sup>

<sup>1</sup>Institute of Health Informatics, University College London, London, UK, NW1 2DA, UK

<sup>2</sup>Research Department of Epidemiology & Public Health, University College London, London, WC1E 7HB, UK

<sup>3</sup>Department of Infectious Disease Epidemiology, London School of Hygiene & Tropical Medicine, London, WC1E 7HT, UK

**V1** First published: 05 Nov 2020, 5:266  
<https://doi.org/10.12688/wellcomeopenres.16387.1>  
Latest published: 05 Nov 2020, 5:266  
<https://doi.org/10.12688/wellcomeopenres.16387.1>

## Abstract

**Background:** Cross-sectional studies indicate that up to 80% of active SARS-CoV-2 infections may be asymptomatic. However, accurate estimates of the asymptomatic proportion require systematic detection and follow-up to differentiate between truly asymptomatic and pre-symptomatic cases. We conducted a rapid review and meta-analysis of the asymptomatic proportion of PCR-confirmed SARS-CoV-2 infections based on methodologically appropriate studies in community settings.

**Methods:** We searched Medline and EMBASE for peer-reviewed articles, and BioRxiv and MedRxiv for pre-prints published before 25/08/2020. We included studies based in community settings that involved systematic PCR testing on participants and follow-up symptom monitoring regardless of symptom status. We extracted data on study characteristics, frequencies of PCR-confirmed infections by symptom status, and (if available) cycle threshold/genome copy number values and/or duration of viral shedding by symptom status, and age of asymptomatic versus (pre)symptomatic cases. We computed estimates of the asymptomatic proportion and 95% confidence intervals for each study and overall using random effect meta-analysis.

**Results:** We screened 1138 studies and included 21. The pooled asymptomatic proportion of SARS-CoV-2 infections was 23% (95% CI 16%-30%). When stratified by testing context, the asymptomatic proportion ranged from 6% (95% CI 0-17%) for household contacts to 47% (95% CI 21-75%) for non-outbreak point prevalence surveys with follow-up symptom monitoring. Estimates of viral load and duration of viral shedding appeared to be similar for asymptomatic and

## Open Peer Review

**Reviewer Status** AWAITING PEER REVIEW

Any reports and responses or comments on the article can be found at the end of the article.

symptomatic cases based on available data, though detailed reporting of viral load and natural history of viral shedding by symptom status were limited. Evidence into the relationship between age and symptom status was inconclusive.

**Conclusion:** Asymptomatic viral shedding comprises a substantial minority of SARS-CoV-2 infections when estimated using methodologically appropriate studies. Further investigation into variation in the asymptomatic proportion by testing context, the degree and duration of infectiousness for asymptomatic infections, and demographic predictors of symptom status are warranted.

### Keywords

SARS-CoV-2, asymptomatic, COVID-19, pandemic, epidemiology



This article is included in the [Coronavirus \(COVID-19\)](#) collection.

**Corresponding author:** Ellen Fragaszy ([ellen.fragaszy@ucl.ac.uk](mailto:ellen.fragaszy@ucl.ac.uk))

**Author roles:** **Beale S:** Data Curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – Original Draft Preparation; **Hayward A:** Conceptualization, Methodology, Supervision, Writing – Review & Editing; **Shallcross L:** Methodology, Supervision, Writing – Review & Editing; **Aldridge RW:** Conceptualization, Methodology, Supervision, Writing – Review & Editing; **Fragaszy E:** Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – Review & Editing

**Competing interests:** AH serves on the UK New and Emerging Respiratory Virus Threats Advisory Group. The other authors declare no competing interests.

**Grant information:** This work was supported by an MRC doctoral studentship (MR/N013867/1) to SB and a Wellcome Trust Clinical Research Career Development Fellowship to RWA (206602). The funders were not actively involved in the design, delivery, or analysis of this research. The views expressed in this publication are those of the authors and not necessarily of the MRC or the Wellcome Trust. AH is an NIHR Senior Investigator. The views expressed in this Article are those of the authors and not necessarily those of the NIHR, or the Department of Health and Social Care.

*The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.*

**Copyright:** © 2020 Beale S *et al.* This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**How to cite this article:** Beale S, Hayward A, Shallcross L *et al.* **A rapid review and meta-analysis of the asymptomatic proportion of PCR-confirmed SARS-CoV-2 infections in community settings [version 1; peer review: awaiting peer review]** Wellcome Open Research 2020, 5:266 <https://doi.org/10.12688/wellcomeopenres.16387.1>

**First published:** 05 Nov 2020, 5:266 <https://doi.org/10.12688/wellcomeopenres.16387.1>

## Introduction

Reports of asymptomatic SARS-CoV-2 infection and potential transmission<sup>1-3</sup> have generated concern regarding the implications of undetected asymptomatic transmission on the effectiveness of public health interventions in the current COVID-19 pandemic<sup>4</sup>. However, estimating the proportion of asymptomatic SARS-CoV-2 infections with viral shedding is challenging as the majority of testing is carried out on symptomatic individuals<sup>5</sup>. Furthermore, longitudinal designs that include symptom follow-up are required to differentiate truly asymptomatic cases, i.e. those that never develop symptoms during infection, from pre-symptomatic cases, i.e. those that shed virus and therefore test positive prior to symptom onset (see Figure 1). While asymptomatic viral shedding has been suggested to comprise up to ~80% of SARS-CoV-2 infections<sup>6-8</sup>, data informing these figures are largely confined to cross-sectional reports that cannot distinguish truly asymptomatic cases from those who are pre-symptomatic at the point of testing (see Figure 1). Interchangeable use of these concepts, i.e. asymptomatic and pre-symptomatic, precludes accurate estimation of the asymptomatic proportion of potentially infectious SARS-CoV-2 cases. Detectable SARS-CoV-2 shedding based on reverse transcriptase polymerase chain reaction (PCR) testing cannot conclusively establish infectiousness in the absence of viral culture<sup>9,10</sup>. However, PCR cycle threshold values provide an informative estimate of viral load and, by extension, probable infectiousness<sup>9</sup>; consequently, PCR-confirmed infection can provide a useful and accessible indicator of potentially infectious cases, including those without symptoms, for epidemiological modelling.

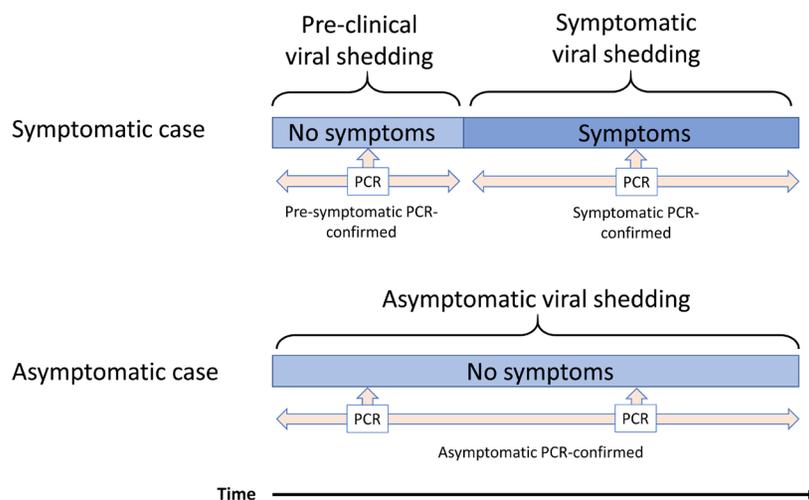
Differences in demographic characteristics of asymptomatic versus symptomatic individuals are also poorly understood.

Age is an important risk factor for COVID-19 severity, with greater risk of poor prognostic outcomes including mortality in older adults<sup>11,12</sup>. Consequently, asymptomatic infection may be less common with increasing age. Understanding the relationship between age and symptom status has important implications for public health interventions.

Given the widespread discussion and potential implications of asymptomatic transmission of SARS-CoV-2, we aimed to rapidly synthesize studies to estimate the asymptomatic proportion of PCR-confirmed cases in community settings (primary outcome). We also aimed to synthesize available data from these studies regarding viral load and duration of viral shedding in asymptomatic community cases compared to pre-symptomatic cases or those symptomatic from baseline (secondary outcome), and the relationship between symptom status and age (secondary outcome). We limited the review to include studies from community settings rather than hospitals and other medical facilities to prevent selection bias towards symptomatic cases. Only studies reporting PCR-confirmed cases rather than exclusive serological studies were included to estimate the proportion of asymptomatic SARS-CoV-2 infection with viral shedding. The review was not extended to estimate the overall asymptomatic proportion including non-shedding serological cases due to the limited number of serological studies, varying interpretation, and ongoing development of valid serological assays for SARS-CoV-2.

## Methodology

This review was reported in line with the PRISMA guidelines<sup>13</sup>. A protocol was not registered due to its status as a rapid review.



**Figure 1. Timeline of symptom development and viral shedding in relation to timing of virological testing.** This figure demonstrates two trajectories of symptom development in cases with detectable viral shedding. The symptomatic case trajectory comprises a period of pre-clinical viral shedding, in which the individual demonstrates no symptoms but tests PCR positive (pre-symptomatic PCR-confirmed). These individuals subsequently develop symptoms and continue to shed virus (symptomatic PCR-confirmed). Consequently, cases with a symptomatic trajectory may appear to be asymptomatic if tested in the pre-clinical shedding period and not followed-up. Asymptomatic cases with viral shedding, conversely, test PCR positive and never go on to develop symptoms across the course of infection (asymptomatic PCR-confirmed).

## Search strategy

We used Ovid to search the Medline and EMBASE databases of peer-reviewed literature (2019- May 05 2020 and search repeated to include period of May 06 2020 to June 10 2020, and subsequently to include June 11 2020 to August 25 2020) using the following search terms for titles and abstracts: (*Coronavirus\** OR *Covid-19* OR *SARS-CoV-2* OR *nCoV*) AND (*asymptomatic*) AND (*polymerase chain reaction* OR *PCR* OR *laboratory-confirmed* OR *confirmed*). We also searched BioRxiv and MedRxiv for titles and abstracts of pre-print manuscripts using the terms “*Covid-19*” + “*asymptomatic*”. We hand-searched the reference lists of all included studies to identify any additional relevant literature.

## Selection criteria

We included studies that met all of the following criteria: 1) human study; AND 2) presented original research or public health COVID-19 surveillance data; AND 3) available in English; AND 4) presented data on polymerase chain reaction (PCR) confirmed COVID-19 cases; AND 5) presented data on PCR testing of exposed or potentially exposed individuals regardless of symptom status (to avoid bias towards symptomatic cases); AND 6) had systematic follow-up at  $\geq 1$  time-point and reporting of symptom status among PCR confirmed cases (to differentiate pre-clinical shedding from truly asymptomatic cases); AND 7) presented data from a community setting (i.e. community and home contact tracing, population screening, traveller screening, community institutional settings such as care homes, schools, or workplaces, occupational exposure including healthcare workers). Studies were excluded if they met any of the following criteria: 1) studies or case series with  $<5$  positive cases and/or  $<20$  total cases (small sample size) due to likely low generalisability of asymptomatic proportions; OR 2) not possible to consistently ascertain the symptomatic status of participants across follow-up; OR 3) inadequate detail about testing strategy (i.e. not possible to discern if all cases were tested systematically); OR 4) recruitment/reporting of patients from acute healthcare settings (e.g. hospitals, medical facilities) due to selection bias towards symptomatic cases.

## Data extraction and analysis

One researcher performed the search and deduplication using Ovid, screened and selected studies, and extracted study details. Two researchers extracted primary outcome data independently and resolved any disagreement by consensus. We extracted the following variables of interest to assess the primary and secondary outcomes and the characteristics and quality of included studies: author names, year of publication, publication type (peer-reviewed article or pre-print), study design, study setting, study country of location, participant age (mean, median, or range as available), participant sex distribution, symptoms comprising symptomatic case definition, duration of symptom history at PCR-confirmation, duration of follow-up symptom monitoring, testing criteria, sample size, number of participants who underwent PCR testing, number of PCR-confirmed cases, number of confirmed cases who remained asymptomatic throughout follow-up, and

cycle threshold or genome copy number values, viral culture results, duration of viral shedding for asymptomatic and pre-/symptomatic cases, and any available data regarding age or age distribution of asymptomatic versus (pre)symptomatic cases if reported.

We performed random-effects meta-analysis using the *metaprop* programme<sup>14</sup> in Stata Version 15 to compute the study-specific and pooled asymptomatic proportion - the primary outcome of this review - with its 95% confidence intervals (Wilson score method) and 95% prediction intervals<sup>15</sup>, applying the Freeman-Tukey transformation (the same analysis can be performed in R). We decided a-priori to use a random effects model to address heterogeneity. The asymptomatic proportion is given as the number of consistently asymptomatic confirmed cases divided by the total number of PCR-confirmed cases who received follow-up (Figure 2). It is important to note that the term asymptomatic proportion is sometimes used to alternatively refer to the asymptomatic proportion of all infections including those that do not shed virus and would not be PCR-confirmed (see Figure 2). To account for potential exposure-driven heterogeneity in asymptomatic proportion, we present findings stratified by testing context as well as overall. Testing context was subdivided into studies comprising exclusive household contacts of an index case, studies comprising contacts from other settings or those (potentially) exposed to an outbreak (including travellers returning from high-prevalence regions), and point prevalence surveys not specifically linked to an outbreak that had follow-up symptom monitoring.

We reported available findings regarding the viral load, duration of viral shedding, and age of asymptomatic and (pre)symptomatic cases, but did not conduct meta-analysis due to sparse reporting and inconsistencies in data presented.

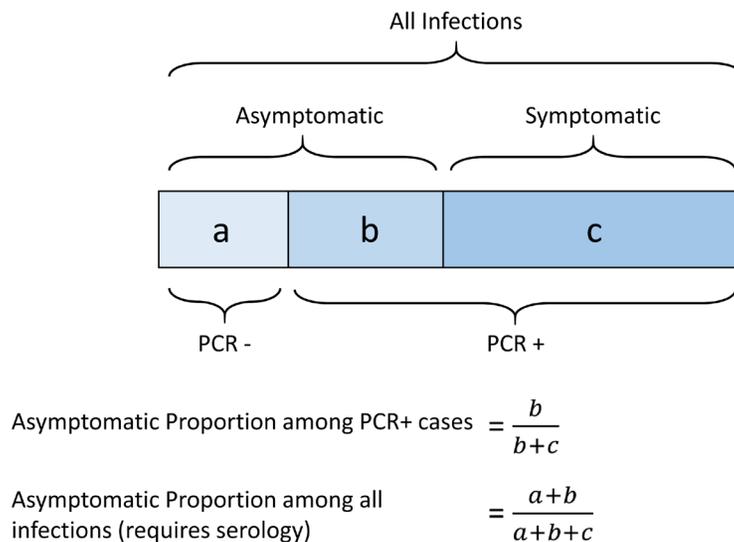
## Risk of bias assessment

We assessed risk of bias based using criteria relevant to the topic of this review adapted from the Joanna Briggs Institute critical appraisal tool for prevalence studies<sup>16</sup> (Table 1). Two researchers independently assessed the risk of bias for each included study and resolved any disagreement by consensus. Bias was assessed according to criteria described in Table 1, with studies graded as very low risk of bias if they were unlikely to have been affected by bias on any of the criteria, low if one criterion may have been affected, moderate if two may have been affected, and high if all three may have been affected. Risk of publication bias across included studies was assessed using a funnel plot and Egger’s test.

## Results

### Records identified

Figure 3 presents an adapted PRISMA flow diagram<sup>13</sup> of the study selection procedure. The search yielded 1077 published articles indexed on OVID and 473 pre-prints. Following deduplication, we screened the titles and abstracts of 1138 published articles and pre-prints, of which we assessed the 133 full texts – including a relevant text identified through



**Figure 2.** Summary classification of clinical and PCR outcomes and calculation of asymptomatic proportions.

**Table 1.** Risk of bias assessment.

| Potential Issue  | Direction of Bias  |
|--|--|
| Information Bias: Initial testing does not identify all infected people shedding virus         | Effect estimate could be biased downwards if PCR testing is more likely to detect symptomatic shedders compared to asymptomatic shedders. This could be because asymptomatic cases shed less virus or shed for a shorter duration. |
| Information Bias: Difficulty distinguishing pre-clinical versus truly asymptomatic             | Effect estimate could be biased upwards if pre-symptomatic cases are misclassified as asymptomatic (see Figure 1)  |
| Non-Participation Bias: Individuals opt out of initial PCR testing or out of symptom follow-up | Effect estimate could be biased in either direction if participation is influenced on symptom-status   |

hand-search of the literature – and included 21 in the present review<sup>17–37</sup>. Three of the 21 included studies comprised household contacts of confirmed cases<sup>26,28,29</sup>. A further three included studies were point prevalence surveys with symptom monitoring follow-up<sup>34–36</sup>, one of which was conducted in a general population sample<sup>36</sup> and the remaining two in nursing home samples<sup>34,35</sup>. The remaining 15 studies involved participants with other epidemiological links to confirmed or suspected cases/outbreaks<sup>17–25,27,30–33</sup>, including five studies based in nursing homes<sup>18,19,24,32,37</sup>, and one study of healthcare workers with occupational exposure to confirmed cases<sup>30</sup>. The healthcare worker study was included as it comprised whole-facility testing following occupational exposure in healthcare workers rather than patients presenting to healthcare settings due to symptoms (see inclusion criteria). Studies were conducted across the following range of countries in Asia, Europe, and North America: China<sup>22,25–27,29</sup>, USA<sup>18,19,28,32,36</sup>, UK<sup>24,35,37</sup>, South Korea<sup>17</sup>, France<sup>20</sup>, Vietnam<sup>21</sup>, Brunei<sup>23</sup>, Italy<sup>30</sup>, Japan<sup>31</sup>, Hong Kong<sup>33</sup>, and Ireland<sup>34</sup>. Risk of bias was rated as very low for two studies<sup>30,33</sup>, low for 15 studies<sup>17–20,22,23,25–29,32,34–36</sup>, and moderate for four studies<sup>21,24,31,37</sup>.

### Asymptomatic proportion of PCR-confirmed SARS-CoV-2 infections in community settings

Estimates of the asymptomatic proportion of PCR-positive SARS-CoV-2 infections for included studies ranged from 0% (95% CI 0-0.8%; Yousaf *et al.*<sup>28</sup>) to 91% (95% CI 73%-98%; Starling *et al.*, 2020<sup>35</sup>). Table 2 reports all asymptomatic proportions with 95% confidence intervals for as well as details of included studies. Based on random-effects meta-analysis (Figure 4), the pooled estimate for the asymptomatic proportion was 23% (95% CI 16%-30%; 95% prediction interval 0.01-57%). There was high heterogeneity:  $Q(20)=253.06$ ,  $p<.001$ ,  $\tau^2=0.11$ ,  $I^2=92.10\%$ . Heterogeneity appeared to be partly influenced by testing context (test for subgroup heterogeneity:  $Q(2)=10.49$ ,  $p=0.01$ ), but remained substantial within these subgroups. Household contact studies demonstrated the lowest asymptomatic proportion estimate of 6% (95% CI 0-17%; heterogeneity  $Q(2)=12.09$ ,  $p<.001$ ,  $\tau^2=0.07$ ,  $I^2=83.46\%$ ), rising to 23% (95% CI 14-32%;  $Q(14)=139.86$ ,  $p<.001$ ,  $\tau^2=0.12$ ,  $I^2=89.99\%$ ) for studies comprising participants with other epidemiological links to SARS-CoV-2 cases or outbreaks, and 47% (95% CI 21-75%;  $Q(2)=47.16$ ,

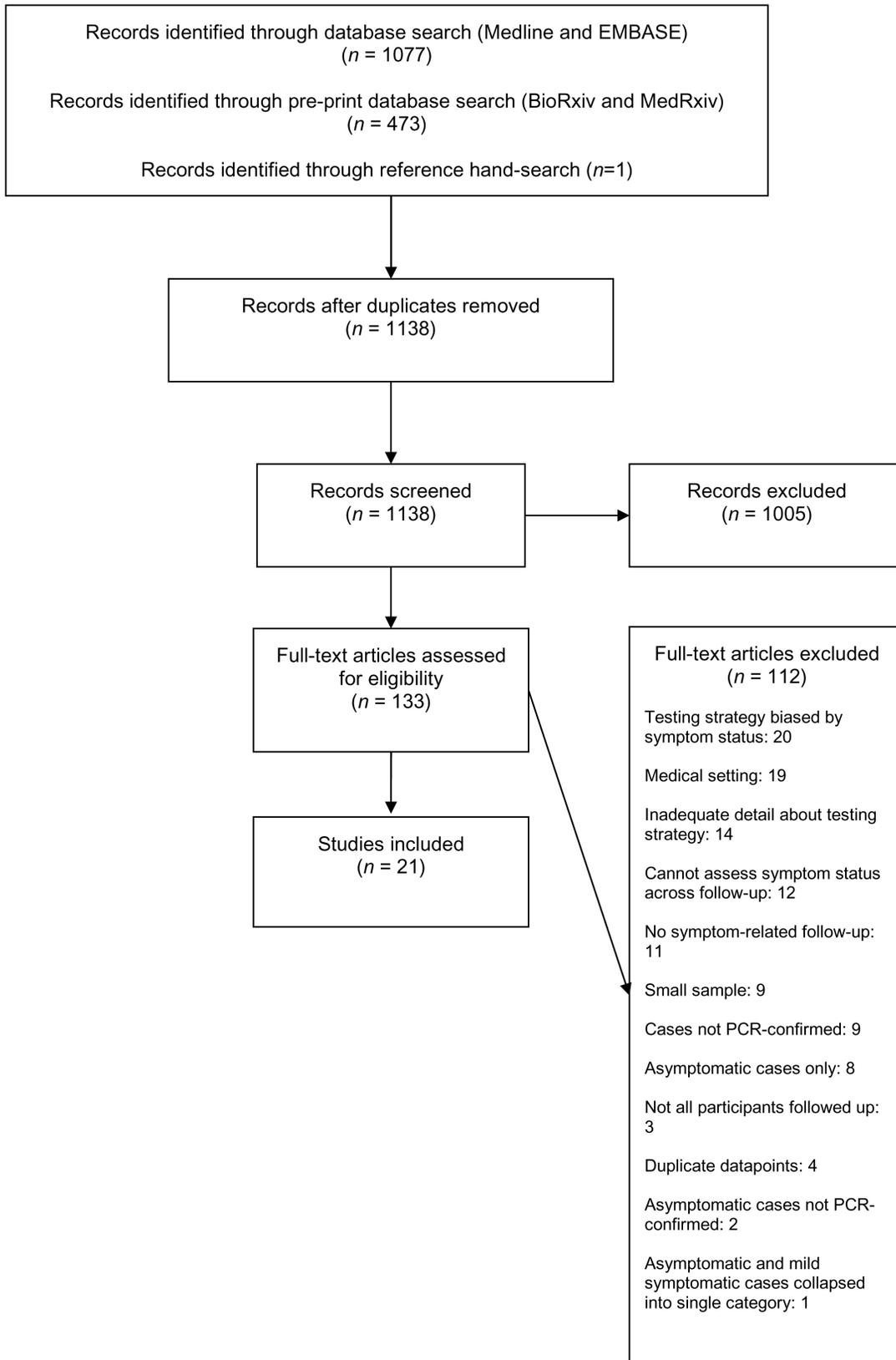


Figure 3. Adapted PRISMA flow diagram of study selection.

**Table 2. Descriptive summary of studies included in meta-analysis.**

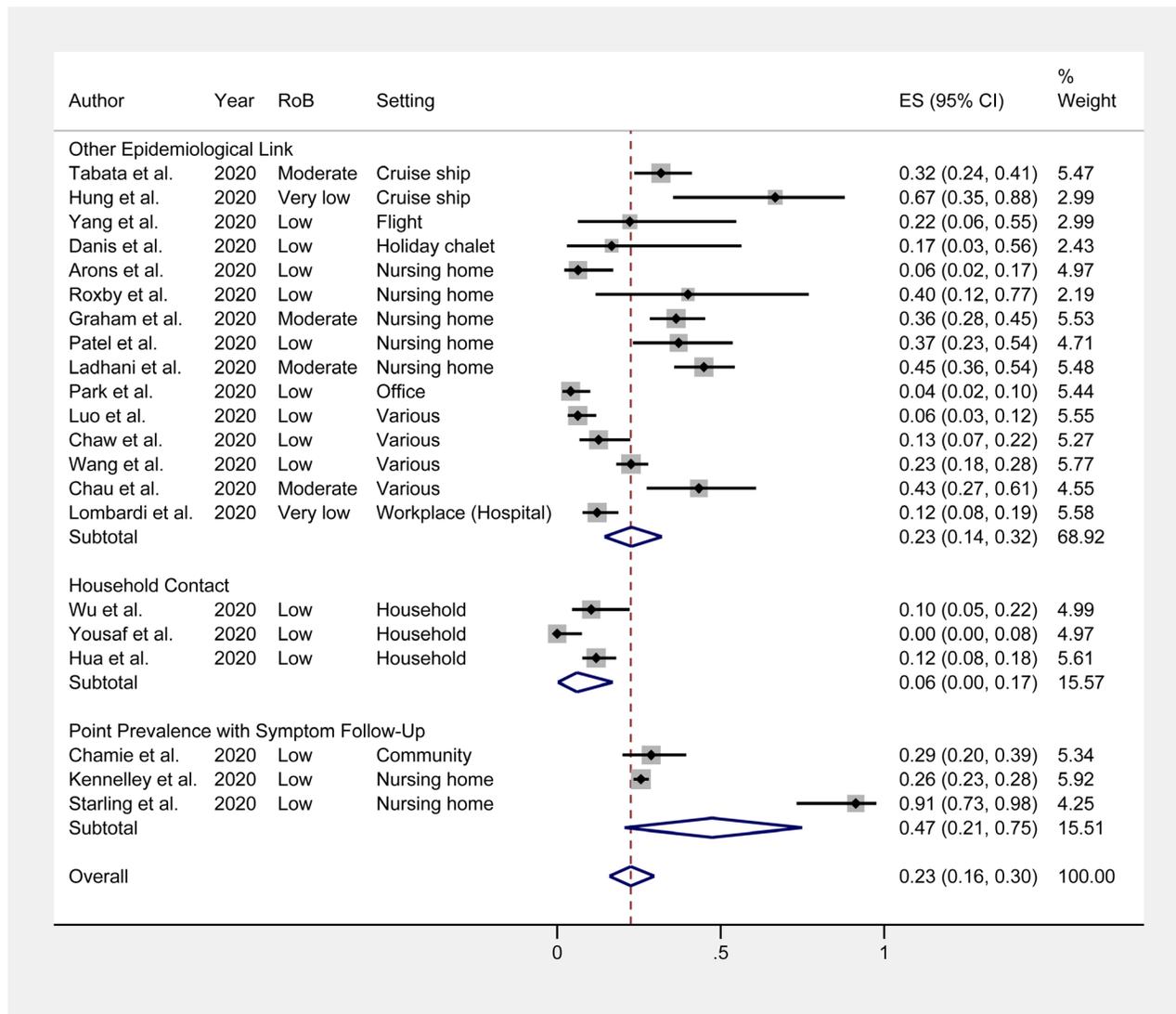
| Reference                  | Country of study | Participant group description   | Study design                   | Testing criteria   | Symptom assessment method  | Symptoms included in symptomatic case definition  | Length of baseline symptom history        | Length of symptom follow-up                        | Tested <i>n</i> | Test Specimen and Frequency   | PCR+ Cases <i>n</i> | Asymptomatic Proportion % (95% CI, <i>n/N</i> ) | Risk of Bias |
|----------------------------|------------------|---|--------------------------------|--|--|---|---|--|-----------------|---|---------------------|---|--------------|
| <b>Park et al. (2020)</b>  | South Korea      | General public: mean age 38 (range 20–80); 72% female (620/857 with demographic data)   | Surveillance                   | Exposed to index case(s)   | Standardised assessment form based on patient interviews                                   | Unspecified   | From date of first symptom onset (if any) | 14 days  | 1143            | Nasopharyngeal and oropharyngeal swabs daily. Collection method (self- vs healthcare worker) unspecified                | 97                  | 4% (2-10%, 4/97)                                | Low          |
| <b>Arons et al. (2020)</b> | USA              | Residents of one nursing home: mean age: 76 ± 10; 63% female (48/76)  | Serial point prevalence survey | Exposed to index case(s)   | Standardised assessment form based on interviews and medical records                       | Fever, cough, shortness of breath, chills, myalgia, malaise, sore throat, runny nose or congestion, confusion or sleepiness, dizziness, headache, diarrhoea, and nausea and/or vomiting.  | Within previous 14 days                   | 7 days   | 76              | Nasopharyngeal and oropharyngeal swabs twice one week apart. Collection method (self- vs healthcare worker) unspecified | 47 <sup>a</sup>     | 6% (2-17%, 3/47)                                | Low          |
| <b>Roxby et al. (2020)</b> | USA              | Residents of one nursing home: mean age = 86 (range 69–102); 77% female (62/80)<br>Staff of one nursing home: mean age 40 (range 16–70); 72% female (45/62) | Surveillance                   | Exposed to index case(s)   | Standardised assessment form based on patient self-report with or without staff assistance | Fever, cough, and other symptoms inc. sore throat, chills, confusion, body aches, dizziness, malaise, headaches, cough, shortness of breath, and/or diarrhoea   | Within previous 14 days                   | 7 days   | 142             | Nasopharyngeal swabs twice one week apart. Collection method (self- vs healthcare worker) unspecified                   | 5                   | 40% (12-77%, 2/5)                               | Low          |
| <b>Danis et al. (2020)</b> | France           | General public (demographic details unknown)  | Surveillance                   | Exposed to index case(s)   | Bespoke (to study) assessment forms based on patient interviews                            | Full list unspecified but included fever, dry cough, wet cough, asthma/ fatigue, chills, sweats, rhinorrhoea, and/or myalgia  | From date of first symptom onset (if any) | 14 days  | 11 <sup>a</sup> | Nasopharyngeal swabs or endotracheal aspirates daily. Collection method (self- vs healthcare worker) unspecified        | 6                   | 17% (3-56%, 1/6)                                | Low          |
| <b>Chau et al. (2020)</b>  | Vietnam          | General public: median age 29 (range 16–60); 50% female (15/30 with follow-up)  | Prospective cohort             | Exposed to index case(s) and returning travellers from high-risk areas | Standardised assessment forms based on participant report                                  | Full list unspecified but included fever, cough, rhinorrhoea, fatigue, diarrhoea, sore throat, muscle pain, headache, abdominal pain, and/or lost sense of smell  | From date of first symptom onset (if any) | 14+ days   | 14000           | Nasopharyngeal swabs daily and saliva at baseline. Collection method (self- vs healthcare worker) unspecified           | 30 <sup>d</sup>     | 43% (27-61%, 13/30)                             | Moderate     |
| <b>Luo et al. (2020)</b>   | China            | General public: median age 38.0 (IQR: 25.0 - 52.0); 50% female (2466/4950)  | Prospective cohort             | Exposed to index case(s)   | Standardised assessment forms from participant self-report                                 | Fever, cough, chill, sputum production, nasal congestion, rhinorrhoea, sore throat, headache, fatigue, myalgia, arthralgia, shortness of breath, difficulty breathing, chest tightness, chest pain, conjunctival congestion, nausea, vomit, diarrhoea, stomach-ache, and/or other | From date of first symptom onset (if any) | Until 2 consecutive negative swabs – up to 30 days | 495             | Oropharyngeal swabs every two days. Swabbing conducted by public health workers.  | 129                 | 6% (3-12%, 8/129)                               | Low          |

| Reference                   | Country of study | Participant group description   | Study design                   | Testing criteria                            | Symptom assessment method  | Symptoms included in symptomatic case definition   | Length of baseline symptom history        | Length of symptom follow-up  | Tested n                                 | Test Specimen and Frequency   | PCR+ Cases n | Asymptomatic Proportion % (95% CI, n/N) | Risk of Bias |
|-----------------------------|------------------|---|--------------------------------|---|--|--|---|--|--|---|--------------|---|--------------|
| <b>Chaw et al. (2020)</b>   | Brunei           | General public: median age 33 (IQR = 29.5); 3.5% female (n=25/71) <sup>a</sup>  | Surveillance                   | Exposed or epidemiological link to outbreak | Digital records on the national health information system database | Fever, cough, runny nose, sore throat  | From date of first symptom onset (if any) | 14 days  | 127                                      | Nasopharyngeal swab. Those with positive swab or who developed symptoms re-tested until two consecutive negative tests (for positives) at unreported frequency. Collection method (self- vs healthcare worker) unspecified. | 71           | 13% (7-22%, 9/71)                       | Low          |
| <b>Graham et al. (2020)</b> | United Kingdom   | Residents of four nursing homes: median age 83 (IQR= 15); 62% female (n=246/394) <sup>b</sup>                                     | Serial point prevalence survey | Exposed to nursing home outbreak            | Case note review and information from medical and nursing team     | New fever, cough and/or breathlessness, newly altered mental status or behaviour, anorexia, diarrhoea or vomiting  | Within previous 14 days                   | 7 days   | 313                                      | Nasopharyngeal and oropharyngeal swabs collected at baseline, with previously unavailable or test-negative participants (re)tested one week later. Collected by healthcare workers.   | 126*         | 35% (27-44%, 44/126)                    | Moderate     |
| <b>Wang et al. (2020)</b>   | China            | General population: mean age 39.3 (SD=16.5); 46% female (n=29/63) <sup>c</sup>  | Surveillance                   | Exposed to index case(s)                    | Medical reports  | Full list unspecified but including cough, fever, shortness of breath and muscle soreness  | From 2 days after exposure event          | Until discharge from quarantine (median 10-13 days for those with and without normal chest x-ray respectively) | Unclear (only 279 positives reported on) | Nasopharyngeal swabs daily. Collection method (self- vs healthcare worker) unspecified.   | 279          | 23% (18-28%, 63/279)                    | Low          |
| <b>Wu et al. (2020)</b>     | China            | General population: median age 43.5 (IQR= 35.8-62.3) for secondary cases and 37 (IQR= 14.5-58) for non-cases. 56% female n=80/143 | Surveillance                   | Exposed to index case(s)                    | Internet-based questionnaires                                      | Fever, cough, shortness of breath, diarrhoea or other common symptoms (including expectoration, haemoptysis, sore throat, nasal obstruction, runny nose, sneeze, headache, muscle ache or fatigue) | Since exposure event                      | 21 days  | 143                                      | Nasopharyngeal and/or oropharyngeal swabs (at Day 1, 7, and 14 for asymptomatic cases and up to 3-day intervals if showed symptoms). Collected by healthcare workers.   | 48           | 10% (5-22%, 5/48)                       | Low          |
| <b>Yang et al. (2020)</b>   | China            | General population: median age 32 (IQR: 26-33); 78% female (7/9) <sup>e</sup>   | Retrospective cohort           | Exposed to confirmed case on flight         | Medical records  | Full list unspecified but including cough, expectoration, myalgia, headache, sore throat, anorexia, fatigue, diarrhoea, nausea, vomiting, chest distress, and dyspnoea                             | From date of first symptom onset (if any) | 14 days  | 325                                      | Throat swab at baseline. Subsequent frequency and collection method (self- vs healthcare worker) unspecified.   | 9            | 22% (6-55%, 2/9)                        | Low          |

| Reference                     | Country of study | Participant group description   | Study design                       | Testing criteria   | Symptom assessment method                    | Symptoms included in symptomatic case definition   | Length of baseline symptom history        | Length of symptom follow-up  | Tested n   | Test Specimen and Frequency  | PCR+ Cases n | Asymptomatic Proportion % (95% CI, n/N) | Risk of Bias |
|-------------------------------|------------------|---|------------------------------------|--|--|--|---|--|--|--|--------------|---|--------------|
| <b>Yousaf et al. (2020)</b>   | USA              | General population: 35% (69/195) <18 years, 46% (89/195) 18–49 years, 15% (29/195) 50–64 years, 4% (8/195) 65+ years; 51% female (99/195) | Prospective cohort                 | Household contacts of confirmed case(s)                                | Standardised questionnaire and symptom diary | Full list unspecified but including fever, chills, myalgia, or fatigue; runny nose, nasal congestion, or sore throat; cough, difficulty breathing, shortness of breath, wheezing, or chest pain; headache, loss of taste, or loss of smell; nausea/vomiting; diarrhoea, and abdominal pain | From date of first symptom onset (if any) | 14 days  | 195  | Nasopharyngeal swab on first and last day of study and if new symptoms were reported   | 47           | 0% (0-0.08%, 0/9)                       | Low          |
| <b>Hua et al. (2020)</b>      | China            | General population: mean age 8.16 (SD: 4.07); 39% female (17/43); 39% children (<4 years; 325/835), 61% (510/835) adults                  | Retrospective cohort               | Family contacts of confirmed case(s) or returning from high-risk areas | Medical and public health records            | Full list unspecified but including fever, cough, stuffy/runny nose, fatigue, diarrhoea, vomiting/abdominal pain, shortness of breath, chest tightness, and headache   | Since exposure to index case(s)           | Until discharge from quarantine (mean=20.2, SD: 7.9, range 3-32 days)                | 835  | Respiratory specimens. Further details of collection unspecified.  | 151          | 12% (8-18%, 18/151)                     | Low          |
| <b>Lombardi et al. (2020)</b> | Italy            | Healthcare workers: mean age 44.5 years; 64% female (1010/1573)   | Surveillance                       | Exposed occupationally to confirmed case(s)                            | Infectious disease notification form         | Fever, cough, dyspnoea, asthenia, myalgia, coryza, sore throat, headache, ageusia or dysgeusia, anosmia or parosmia, ocular symptoms, diarrhoea, nausea, and vomiting  | 14 days                                   | Until end of study for patients asymptomatic at baseline                             | 1573   | Nasopharyngeal swabs at baseline and subsequently for positive cases at unspecified frequency. Collection method (Self vs healthcare workers) unspecified. | 139          | 12% (8-19%, 17/139)                     | Very low     |
| <b>Tabata et al. (2020)</b>   | Japan            | General population: median age 68 (IQR: 47-75); 48% female (50/104)   | Surveillance/ Retrospective cohort | Exposed to confirmed case(s) on cruise ship – whole ship screening     | Medical records based on clinical interviews | Unspecified  | From beginning of quarantine period       | Until discharge or end of study (whichever was earliest); median 10 days (IQR: 7-10) | Unclear for study. 3711 tested on ship but not all isolated in study facility. | Pharyngeal swabs or sputum specimens. Further details of collection unspecified.   | 104          | 32% (24-41%, 33/104)                    | Moderate     |
| <b>Patel et al. (2020)</b>    | USA              | Residents of one nursing home: median age 82 (IQR: 72-92); 69% female (24/35)   | Surveillance                       | Exposed to nursing home outbreak                                       | Interview by nursing staff                   | Fever, cough, shortness of breath, hypoxia, sore throat, nasal congestion, diarrhoea decreased appetite, chills, myalgias, headaches, new onset confusion  | From baseline                             | 30 days  | 118  | Nasopharyngeal swab at single time-point. Collected by healthcare workers.   | 35           | 37% (23-54%, 13/35)                     | Low          |
| <b>Hung et al. (2020)</b>     | Hong Kong        | General population: median age 58 (IQR: 56-61) for positive participants and for negative 64 (IQR: 56-70); 59% female (127/215)           | Prospective cohort                 | Exposed to confirmed case(s) on cruise ship                            | Questionnaire                                | Full list unspecified but including chills and rigors, cough, sputum, malaise, myalgia, diarrhoea, rhinorrhoea, and fever  | From baseline                             | 14+ days   | 215  | Nasopharyngeal, throat, and rectal swabs at baseline, and Days 4, 8, and 12. Collected by healthcare workers.  | 9            | 67% (35-88%, 6/9)                       | Very low     |

| Reference                      | Country of study | Participant group description   | Study design       | Testing criteria   | Symptom assessment method   | Symptoms included in symptomatic case definition   | Length of baseline symptom history                 | Length of symptom follow-up | Tested n | Test Specimen and Frequency  | PCR+ Cases n    | Asymptomatic Proportion % (95% CI, n/N) | Risk of Bias |
|--------------------------------|------------------|---|--------------------|--|---|--|--|-----------------------------|----------|--|-----------------|---|--------------|
| <b>Kennelley et al. (2020)</b> | Ireland          | Residents and staff of 28 nursing homes. Further demographic detail unspecified.  | Surveillance       | National point-prevalence testing programme for nursing homes                | Survey  | Cough, fever, dyspnoea, and any new-onset symptoms deemed notable by medical officer/general practitioner  | 7 days   | 7 days                      | 2718     | Nasopharyngeal swab at single time-point. Further details of collection unspecified.                         | 1374            | 26% (23-28%, 352/1374)                  | Low          |
| <b>Starling et al. (2020)</b>  | UK               | Residents of 15 nursing homes <sup>a</sup> ; median age ranged across homes from 36.0-90.5 (range 18-106); sex distribution ranged across homes from 40.0-78.6% female  | Surveillance       | Local authority point-prevalence testing programme for nursing homes         | Interview with care home managers   | New continuous cough or fever  | From baseline                                      | 14 days                     | 441      | Upper respiratory tract specimens at single time-point. Collected by healthcare workers.                     | 23              | 91% (73-98%, 21/23)                     | Low          |
| <b>Chamie et al. (2020)</b>    | USA              | General population: 3% 4-10 years (118/3953); 4% 11-17 years (141/3953); 64% 18-50 years (2532/3953); 24% 51-70 years (951/3953); 5% > 70 years (211/3953); 43% female (1699/3953)  | Prospective cohort | Resident, bordering, or employed within a local inner-city census-tract area | In-person interview at baseline and follow-up by community team if positive | Unspecified  | Unspecified but includes symptoms prior to testing | 14 days                     | 3953     | Oropharyngeal or mid-turbinate nasal swab at single time-point. Collected by healthcare workers.             | 80 <sup>b</sup> | 29% (20-39%, 23/80)                     | Low          |
| <b>Ladhani et al. (2020)</b>   | UK               | Residents and staff of 6 nursing homes; median age for positive participants 85 (78-90) for residents and 47 (38-57) for staff; for negative participants 85 (80-91) for residents and 47 (35-56) for staff; 74% female (386/518) | Surveillance       | Exposed to nursing home outbreak   | Datasheet and daily phone call with research worker                         | Fever; persistent cough; sore throat; shortness of breath; anosmia; new-onset confusion; reduced alertness; fatigue; lethargy; reduced mobility; diarrhoea | 14 days  | 14 days                     | 518      | Nasal swabs at single time-point. Collected by healthcare workers for residents and self-collected by staff. | 158             | 45% (36-54%, 77/158)                    | Moderate     |

<sup>a</sup> includes only high-risk contacts isolated and followed-up in France; <sup>b</sup> excludes one case that had history of previous positive test but was negative at facility-wide study testing; <sup>c</sup> excludes one case with negative PCR at baseline and positive PCR at follow-up PCR, as symptom monitoring not possible; <sup>d</sup> not including 19 PCR-positive cases that refused follow-up; <sup>e</sup> demographics only reported for PCR- positive cases; <sup>f</sup> includes one case excluded from present analyses as identified via symptoms and not systematic PCR-testing; <sup>g</sup> only residents included as staff testing was not systematic and was partially based on symptom status; <sup>h</sup> demographics reported for asymptomatic participants only; <sup>i</sup> demographics reported for PCR-positive cases or those with clinical abnormalities only; <sup>j</sup> excludes index case and two PCR-positive case without symptom follow-up; <sup>k</sup> demographics for children only but adults included in clinical outcomes; <sup>l</sup> 8 participants excluded because of insufficient data; <sup>m</sup> staff excluded due to requirement to be 'fit to work' biasing sample towards asymptomatic participants; <sup>n</sup> excluding 3 PCR-positive participants without symptom status classification/follow-up



**Figure 4. Meta-analysis results for COVID-19 asymptomatic proportion in community studies.** ES (effect size) = asymptomatic proportion;  $I^2$  = heterogeneity; asymptomatic proportions are given in decimal form.

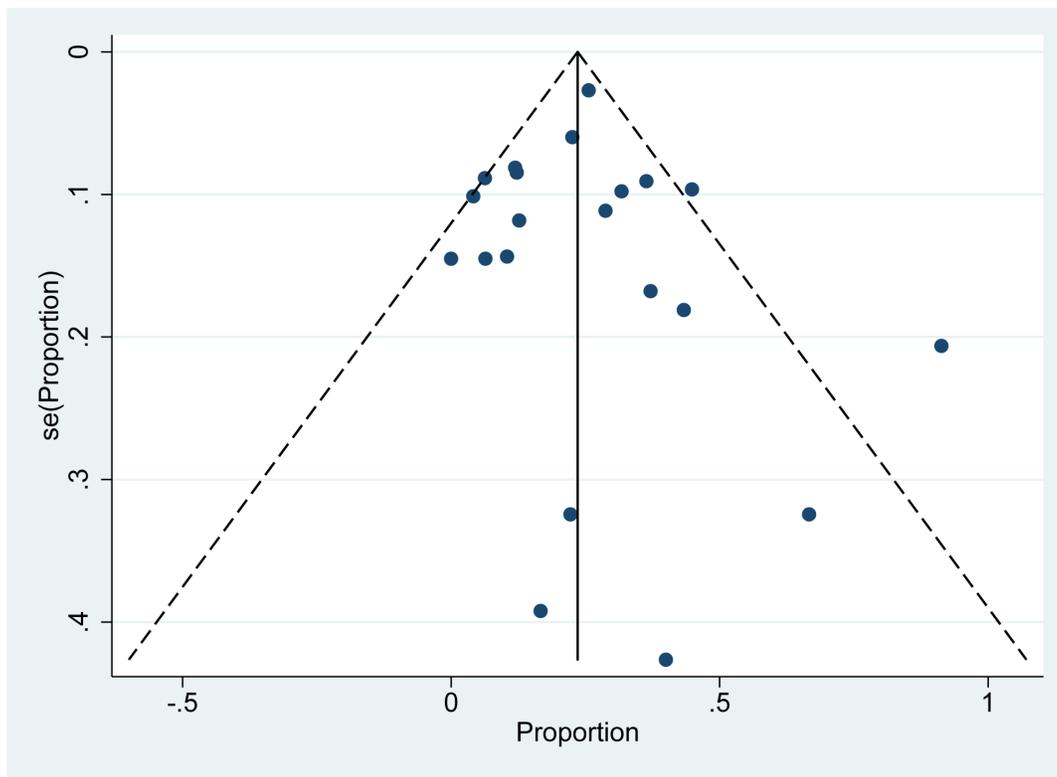
$p < .001$   $\tau^2 = 0.23$ ,  $I^2 = 95.76\%$ ) for point prevalence surveys with symptom follow-up and without direct links to outbreaks/cases. Data were limited for studies exclusively involving household contacts or point prevalence surveys (both  $n=3$  studies).

The funnel plot (Figure 5) and Egger's test did not indicate publication bias across studies included in the meta-analysis:  $t=0.23$ ,  $p=0.82$ , 95% CI: -0.97, 1.20.

#### Viral load and duration of viral shedding

Eight of the twenty-one included studies reported data regarding the CT values/viral load and/or duration of viral shedding for asymptomatic cases versus pre-symptomatic cases and/or those symptomatic from baseline. Differences in methodology and reporting precluded meta-analysis.

Five studies reported CT values and/or genome copy number by symptom status. One of these studies, Hung *et al.*<sup>33</sup>, found lower median baseline genome copy number in asymptomatic (3.86 log<sub>10</sub> copies/mL) than symptomatic participants (7.62 log<sub>10</sub> copies/mL). The remaining four studies all reported similar CT values for asymptomatic and symptomatic participants. Arons *et al.*<sup>18</sup> reported similar baseline median cycle threshold values (CT) for asymptomatic (CT =25.5), pre-symptomatic (CT=23.1), and symptomatic (CT=24.5) cases. Infectious virus was isolated by viral culture from 33% (1/3) of available asymptomatic case specimens, 70.8% (17/24) of pre-symptomatic case specimens, and 65.0% (16/20) for symptomatic case specimens<sup>18</sup>. Chamie *et al.* (2020)<sup>36</sup> also found that median CT values across samples were not significantly different between asymptomatic (CT=24,



**Figure 5.** Funnel plot for meta-analysis of COVID-19 asymptomatic proportion in community studies.

IQR: 19-26) and symptomatic individuals (CT=24, IQR: 19-25). Pre-symptomatic individuals appeared to have higher median CT values if seronegative and similar values if seropositive, but numerical detail was not reported overall for this group. Ladhani *et al.* (2020)<sup>37</sup> also found no significant difference in baseline CT values between asymptomatic, pre-symptomatic, symptomatic, and post-symptomatic (i.e. reported symptoms in the two weeks prior to positive PCR result) participants; exact values were not provided. Chau *et al.*<sup>21</sup> also reported similar baseline cycle threshold values for asymptomatic and symptomatic cases, though further numeric detail was not reported. When including all PCR results across follow-up for asymptomatic versus symptomatic cases (including negative PCR results), asymptomatic cases appeared to demonstrate lower CT values overall, which was proposed to indicate faster viral clearance<sup>21</sup>.

Direct investigation of duration of viral shedding was limited. Lombardi *et al.*<sup>30</sup> found that median duration from positive test to first negative test was shorter in asymptomatic participants (22 days; IQR: 15–30) than symptomatic ones (29 days; IQR: 24–31), but the difference was not statistically significant. Danis *et al.*<sup>20</sup> reported that the single asymptomatic case demonstrated the same viral load dynamics as one of the five symptomatic cases, with respective viral shedding periods of 7 and 6 days.

#### Age of symptomatic versus asymptomatic cases

Six studies<sup>21,27,29,31,33,37</sup> reported information regarding the age of asymptomatic versus symptomatic cases. Variation in measurement and reporting precluded meta-analysis. Findings are reported in Table 3. Three studies indicated no significant difference in age between symptomatic and asymptomatic cases, while three studies suggested that asymptomatic cases tended to be younger than those with symptoms. Five studies were conducted in general population samples (contacts/potential contacts of confirmed cases or returning travellers), and one study was conducted in nursing home residents and staff with results stratified for these groups. Only one study<sup>29</sup> reported a substantial child sub-sample (<14 years old), and found a higher asymptomatic proportion for infected children (23%  $n=10/43$ ) than adults (7%,  $n=8/108$ ).

#### Discussion

Accurate estimates of the asymptomatic proportion of SARS-CoV-2 infections depend on appropriate study designs that systematically detect asymptomatic viral shedding and follow these cases up to differentiate truly asymptomatic infections from pre-clinical shedding. We calculated that an overall estimate of 23% of PCR-confirmed SARS-CoV-2 infections in community settings were asymptomatic, with a 95% confidence interval between 16%-30%. These findings do not support claims<sup>6-8</sup> of a very high asymptomatic proportion

**Table 3. Reported findings for age of asymptomatic versus symptomatic cases.**

| Study                        | Sample  | Findings  |
|------------------------------|---|---|
| Chau <i>et al.</i> (2020)    | General public (contacts of confirmed case or returning travellers)         | Median age of asymptomatic versus symptomatic participants: 30 (range 16-60) versus 27 (range 18-58)  |
| Yang <i>et al.</i> (2020)    | General public exposed to index case on flight                              | Median age of asymptomatic and symptomatic participants: 26 (IQR: 25.5-26.5) versus 33 (IQR: 29-45)<br><br>*note: very small asymptomatic sample ( $n=2$ )  |
| Hua <i>et al.</i> (2020)     | General public exposed to household cases or returning from high-risk areas | 23% of infected children ( $\leq 14$ years, $n=10/43$ ) were asymptomatic versus 7% of infected adults ( $n=8/108$ ), with children comprising 56% ( $n= 10/18$ ) of asymptomatic cases and adults 44% ( $n= 8/18$ )  |
| Tabata <i>et al.</i> (2020)  | General public exposed to outbreak on cruise ship                           | Median age of asymptomatic versus symptomatic participants: 70 (IQR: 57-75) versus 68 (IQR: 56-74)  |
| Hung <i>et al.</i> (2020)    | General public exposed to outbreak on cruise ship                           | Median age of asymptomatic and symptomatic participants: 57 (IQR: 47-59) versus 68 (IQR: 59-68)   |
| Ladhani <i>et al.</i> (2020) | Nursing home residents and staff  | Median age of asymptomatic, post-symptomatic, pre-symptomatic, and symptomatic residents: 84 (IQR: 78-90); 88 (IQR: 85-91); 84 (IQR: 80-91); 87 (IQR: 80-91)<br><br>Median age of asymptomatic, post-symptomatic, pre-symptomatic, and symptomatic staff: 50 (IQR: 40-56); 54, (41-59); 38 (IQR 34-49); 40 (IQR: 26-55) |

for PCR-confirmed infections (up to 80%) and highlight the importance of distinguishing between asymptomatic and pre-symptomatic cases. Heterogeneity in estimates of the asymptomatic proportion, however, was partly influenced by variation between testing contexts. Subgroup estimates range from 6% (95%CI 0-17%) for household contacts, increasing to 23% (95% CI 14-32%) for participants with other epidemiological links to case(s) or outbreaks, and the highest estimate of 47% (95% CI 21-74%) for point prevalence studies not directly linked to contact(s)/outbreaks.

These findings should be interpreted with caution in terms of the relationship between exposure and symptom status<sup>38</sup>. The assumption that household contacts of index cases may experience frequent and intense exposure with limited protection compared to other groups, and conversely that participants in non-outbreak studies may have more limited exposure, could not be empirically verified in the present review. Confidence intervals for subgroup asymptomatic proportions overlapped substantially, and data were limited for both the household contact and the point prevalence survey with symptom follow-up categories (both  $n=3$  included studies). Furthermore, the estimate for point prevalence surveys was affected by one study<sup>35</sup> with a very high asymptomatic proportion (91%); this estimate was likely influenced by the limited symptomatic case definition of new-onset cough or fever. Estimates for the other two studies were similar to the 'other epidemiological link' category (26% and 29%). Only one of the point prevalence studies with symptom follow-up<sup>36</sup> was conducted in a general population sample. Furthermore, the 'other epidemiological link' category comprised a variety of study

testing contexts, including studies that combined household contacts with participants with less intensive exposure, which likely contributed to substantial within-category heterogeneity. Despite these substantial limitations, further investigation is warranted into variability in the asymptomatic proportion across testing contexts as more data become available.

This effect of study context may partially account for differences between the overall estimate of the asymptomatic proportion in the current review and higher estimates from other studies. Notably, early population-based data collected from English households by the Office for National Statistics suggested that only 22% (95% CI 14-32%) of the 88 individuals who tested positive for COVID-19 thus far reported any symptoms, rising to 29% (95% CI 19-40%) of the 76 individuals tested repeatedly<sup>8</sup>. Similarly, 69% of another English community sample recruited regardless of symptom status reported no symptoms in the seven days up to their positive PCR result<sup>39</sup>. However, neither of these studies systematically followed-up cases regarding their symptoms across the course of infection, potentially overestimating the asymptomatic proportion and precluding inclusion in this review. Furthermore, findings were affected by the small sample size and consequently wide confidence intervals due to testing at a period of relatively low COVID-19 incidence in the population, as well as potential false positive PCR tests leading to an overestimate of asymptomatic cases. While some of these issues may have impacted studies included in the present review, the careful screening of study design and methodology done as part of this review was reflected in the overall very low or low risk of bias on assessed criteria for all but four included

studies. An additional strength of our review is the systematic search of both peer-reviewed published literature and preprint studies which has enabled us to capture the most up to date estimates available.

Although this review identifies PCR-confirmed cases, PCR-confirmation and symptom-status alone cannot establish whether cases are infectious and, if so, the degree or duration of their infectiousness. Case reports, however, have indicated potential transmission of SARS-CoV-2 from some asymptomatic index cases<sup>1,2,9,21</sup>. The balance of evidence regarding viral load in the present review indicates that asymptomatic cases had similar baseline or overall median viral loads to pre-symptomatic and symptomatic cases. Virological evidence suggests that infectious SARS-CoV-2 can be isolated by viral culture from samples with cycle threshold values up to 33, though the proportion of infectious virus decreases at higher cycle threshold values (i.e. lower viral load)<sup>40</sup>. While median baseline cycle threshold values for all symptom status groups (23.1-25.5) reported by Arons *et al.*<sup>18</sup> fell well within this limit, infectious virus was isolated from only 33% of asymptomatic baseline samples, compared to 71% of pre-symptomatic and 65% of symptomatic samples. These findings should be interpreted with caution given the very small sample of asymptomatic specimens ( $n=3$ ). Overall, clear reporting of cycle threshold values across follow-up by symptom status was lacking in included studies. This is an important area for further research given that the degree and duration of the infectious period for asymptomatic cases, as well as the overall proportion of virus-shedding cases that are asymptomatic, influence the contribution of asymptomatic cases to SARS-CoV-2 transmission at a population level.

Evidence regarding the duration of SARS-CoV-2 shedding by symptom status was very limited, with two studies suggesting no substantial difference in viral clearance times for asymptomatic and symptomatic cases. Duration of shedding varied widely between participants across all symptom status groups in included studies. The sample of asymptomatic cases in studies that reported duration of viral shedding also tended to be small, and the natural history of viral excretion by symptom status remains unclear. Further inquiry into the degree of preclinical shedding for pre-symptomatic cases, although not the focus of this review, is also warranted. The contribution of asymptomatic and pre-symptomatic cases to the overall spread of infection cannot be accurately inferred in the absence of high-quality evidence assessing the infectiousness of such cases<sup>41</sup>.

Evidence was also split regarding age and symptom status, with three studies indicating no difference in age between asymptomatic and symptomatic cases and three studies indicating that asymptomatic cases may tend to be younger than those with symptoms. Samples in the present study – both within the age-related analysis and in the meta-analysis overall – tended to comprise primarily or exclusively of adults, and one study with a substantial child subsample<sup>29</sup> found that a larger proportion of infected children were asymptomatic (23%) than

adults (7%). Further comparison of the asymptomatic proportion for children and adults is required.

An important limitation of this review was the variability between symptomatic case definitions across included studies. Only eight of the twenty-one included studies<sup>18,22–24,30,32,35,37</sup> described the full range of symptoms included within their symptomatic case definitions, while a further ten studies<sup>19,20,23,25–29,33,34</sup> reported details of symptoms endorsed by participants but did not specify whether or which additional symptoms were assessed as part of their case definitions and three<sup>17,31,36</sup> provided no detail. While a similar range of symptoms appear to have been monitored/endorsed across most included studies, it is possible that symptomatic case identification may have been affected by reporting bias and consequently that the true proportion of symptomatic cases was underestimated. Notably, Starling *et al.*<sup>35</sup> – the study with the highest reported asymptomatic proportion (91%) – used a very limited case definition of new-onset cough or fever. The reported proportion likely reflects individuals not meeting this case definition and excludes cases with other symptom profiles. This issue is particularly relevant given that unusual symptoms such as dysosmia/anosmia – only explicitly investigated by four studies<sup>21,28,30,37</sup> – and dysgeusia/ageusia – only explicitly investigated by two studies<sup>28,30</sup> – may be the primary or sole symptom for some COVID-19 cases<sup>42–44</sup>. Demographic reporting across studies was also limited and it was not possible to stratify findings by further demographic characteristics. Estimates of the asymptomatic proportion may vary across population subgroups and this is a relevant area for future enquiry.

We included only studies with symptom-related follow-up to prevent symptom status misclassification. However, overestimation of the asymptomatic proportion may still occur in contact tracing studies initiated during established outbreaks, such as Graham *et al.*<sup>24</sup>, if baseline symptomatic participants are classified as index cases and systematically excluded from the asymptomatic proportion. This review was also limited to estimating the asymptomatic proportion of virologically confirmed infections. The asymptomatic proportion of infection varies depending on whether infections are identified using virological or serological methods<sup>45</sup>. PCR confirmation, which identifies infection with viral shedding, is informative for modelling transmission potential. However, review of the asymptomatic proportion of total infections based on emerging serological evidence – which identifies infections regardless of viral shedding – will be informative to understand how far SARS-CoV-2 has spread within populations and investigate evidence of immunity following asymptomatic infection<sup>46</sup>.

Overall, this review provides preliminary evidence that, when investigated using methodologically appropriate studies, a substantial minority of SARS-CoV-2 infections with viral shedding are truly asymptomatic. These findings indicate that testing should not be exclusively limited to symptomatic individuals. Further research identifying distinguishing features

(e.g. age) and testing contexts for truly asymptomatic cases, as well as their transmission potential, is recommended to inform testing programmes. These findings also highlight the importance of other public health measures, such as promoting social distancing and wearing face coverings in public places, regardless of symptom status.

## Data availability

### Underlying data

University College London Research Data Repository: A Rapid Review and Meta-Analysis of the Asymptomatic Proportion of PCR-Confirmed SARS-CoV-2 Infections in Community Settings. <http://doi.org/10.5522/04/12344135.v347>.

This project contains the following underlying data:

- Asymptomatic meta-analysis V2.csv. (Data used to conduct meta-analysis of asymptomatic proportion.)

## Reporting guidelines

University College London Research Data Repository: PRISMA checklist for 'A rapid review and meta-analysis of the asymptomatic proportion of PCR-confirmed SARS-CoV-2 infections in community settings'. <http://doi.org/10.5522/04/12344135.v347>.

Data are available under the terms of the [Creative Commons Attribution 4.0 International license \(CC-BY 4.0\)](https://creativecommons.org/licenses/by/4.0/).

## References

\* indicates inclusion in current meta-analysis

- Pan X, Chen D, Xia Y, et al.: **Asymptomatic cases in a family cluster with SARS-CoV-2 infection.** *Lancet Infect Dis.* 2020; **20**(4): 410–1. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Bai Y, Yao L, Wei T, et al.: **Presumed Asymptomatic Carrier Transmission of COVID-19.** *JAMA.* 2020; **323**(14): 1406–7. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Chan JFW, Yuan S, Kok KH, et al.: **A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster.** *Lancet.* 2020; **395**(10223): 514–23. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Gandhi M, Yokoe DS, Havlir DV: **Asymptomatic Transmission, the Achilles' Heel of Current Strategies to Control Covid-19.** *N Engl J Med.* 2020; **382**(22): 2158–2160. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Department of Health and Social Care: **Coronavirus (COVID-19): getting tested.** 2020. [Reference Source](#)
- Day M: **Covid-19: four fifths of cases are asymptomatic, China figures indicate.** *BMJ.* 2020; **369**: m1375. [PubMed Abstract](#) | [Publisher Full Text](#)
- COVID-19: What proportion are asymptomatic? - CEBM.** CEBM. (accessed May 17, 2020). [Reference Source](#)
- Office for National Statistics: **Coronavirus (COVID-19) Infection Survey Pilot: 5 June 2020.** [Reference Source](#)
- Furukawa NW, Brooks JT, Sobel J: **Evidence Supporting Transmission of Severe Acute Respiratory Syndrome Coronavirus 2 While Presymptomatic or Asymptomatic.** *Emerg Infect Dis.* 2020; **26**(7): e201595. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Joynt GM, Wu WK: **Understanding COVID-19: what does viral RNA load really mean?** *Lancet Infect Dis.* 2020; **20**(6): 635–636. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Wu C, Chen X, Cai Y, et al.: **Risk Factors Associated With Acute Respiratory Distress Syndrome and Death in Patients With Coronavirus Disease 2019 Pneumonia in Wuhan, China.** *JAMA Intern Med.* 2020; **180**(7): 934–943. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Fang X, Li S, Yu H, et al.: **Epidemiological, comorbidity factors with severity and prognosis of COVID-19: a systematic review and meta-analysis.** *Aging (Albany NY).* 2020; **12**(13): 12493–12503. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Moher D, Liberati A, Tetzlaff J, et al.: **Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.** *BMJ.* 2009; **339**: b2535. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Nyaga VN, Arbyn M, Aerts M: **Metaprop: a Stata command to perform meta-analysis of binomial data.** *Arch Public Health.* 2014; **72**(1): 39. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Int'Hout J, Ioannidis JPA, Rovers MM, et al.: **Plea for routinely presenting prediction intervals in meta-analysis.** *BMJ Open.* 2016; **6**(7): e010247. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Munn Z, Moola S, Riitano D, et al.: **The development of a critical appraisal tool for use in systematic reviews addressing questions of prevalence.** *Int J Health Policy Manag.* 2014; **3**(3): 123–8. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Park SY, Kim YM, Yi S, et al.: **Coronavirus Disease Outbreak in Call Center, South Korea.** *Emerg Infect Dis.* 2020; **26**(8): 1666–1670. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Arons MM, Hatfield KM, Reddy SC, et al.: **Presymptomatic SARS-CoV-2 Infections and Transmission in a Skilled Nursing Facility.** *N Engl J Med.* 2020; **382**(22): 2081–2090. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Roxby AC, Greninger AL, Hatfield KM, et al.: **Detection of SARS-CoV-2 Among Residents and Staff Members of an Independent and Assisted Living Community for Older Adults - Seattle, Washington, 2020.** *MMWR Morb Mortal Wkly Rep.* 2020; **69**(14): 416–8. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Danis K, Epaulard O, Bénet T, et al.: **Cluster of coronavirus disease 2019 (Covid-19) in the French Alps, 2020.** *Clin Infect Dis.* 2020; **71**(15): 825–832. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Chau NVV, Lam VT, Dung NT, et al.: **The natural history and transmission potential of asymptomatic SARS-CoV-2 infection.** *medRxiv.* 2020; 2020.04.27.20082347. [Publisher Full Text](#)
- \*Luo L, Liu D, Liao XL, et al.: **Modes of contact and risk of transmission in COVID-19 among close contacts.** *medRxiv.* 2020. [Publisher Full Text](#)
- \*Chaw L, Koh WC, Jamaludin SA, et al.: **SARS-CoV-2 transmission in different settings: Analysis of cases and close contacts from the Tablighi cluster in Brunei Darussalam.** *medRxiv.* 2020. [Publisher Full Text](#)
- \*Graham NS, Junghans C, Downes R, et al.: **SARS-CoV-2 infection, clinical features and outcome of COVID-19 in United Kingdom nursing homes.** *medRxiv.* 2020. [Publisher Full Text](#)
- \*Wang Y, Tong J, Qin Y, et al.: **Characterization of an asymptomatic cohort of SARS-CoV-2 infected individuals outside of Wuhan, China.** *Clin Inf Dis.* 2020; ciaa629. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Wu J, Huang Y, Tu C, et al.: **Household Transmission of SARS-CoV-2, Zhuhai, China, 2020.** *Clin Inf Dis.* 2020; ciaa557. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Yang N, Shen Y, Shi C, et al.: **In-flight transmission cluster of COVID-19: a retrospective case series.** *Infect Dis (Lond).* 2020; **52**(12): 891–901. [PubMed Abstract](#) | [Publisher Full Text](#)
- \*Yousaf AR, Duca LM, Chu V, et al.: **A prospective cohort study in non-hospitalized household contacts with SARS-CoV-2 infection: symptom profiles and symptom change over time.** *Clin Infect Dis.* 2020; ciaa1072. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Hua CZ, Miao ZP, Zheng JS, et al.: **Epidemiological features and viral shedding in children with SARS-CoV-2 infection.** *J Med Virol.* 2020. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- \*Lombardi A, Consonni D, Carugno M, et al.: **Characteristics of 1573 healthcare workers who underwent nasopharyngeal swab testing for SARS-CoV-2 in Milan, Lombardy, Italy.** *Clin Microbiol Infect.* 2020; **26**(10): 1413.

e9-1413.e13.

- [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
31. \*Tabata S, Imai K, Kawano S, *et al.*: **Clinical characteristics of COVID-19 in 104 people with SARS-CoV-2 infection on the *Diamond Princess* cruise ship: a retrospective analysis.** *Lancet Infect Dis.* 2020; **20**(9): 1043–50. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  32. \*Patel MC, Chaisson LH, Borgetti S, *et al.*: **Asymptomatic SARS-CoV-2 infection and COVID-19 mortality during an outbreak investigation in a skilled nursing facility.** *Clin Infect Dis.* 2020; **ciaa763**. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  33. \*Hung IFN, Cheng VCC, Li X, *et al.*: **SARS-CoV-2 shedding and seroconversion among passengers quarantined after disembarking a cruise ship: a case series.** *Lancet Infect Dis.* 2020; **20**(9): 1051–60. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  34. \*Kennelly SP, Dyer AH, Martin R, *et al.*: **Asymptomatic carriage rates and case-fatality of SARS-CoV-2 infection in residents and staff in Irish nursing homes.** *medRxiv.* 2020. [Publisher Full Text](#)
  35. \*Starling A, White E, Showell D, *et al.*: **Whole Care Home Testing for Covid-19 in a Local Authority Area in the United Kingdom.** *medRxiv.* 2020. [Publisher Full Text](#)
  36. \*Chamie G, Marquez C, Crawford E, *et al.*: **SARS-CoV-2 Community Transmission During Shelter-in-Place in San Francisco.** *medRxiv.* 2020. [Publisher Full Text](#)
  37. \*Ladhani S, Yimmy Chow J, Janarthanan R, *et al.*: **Investigation of SARS-CoV-2 Outbreaks in Six Care Homes in London, April 2020: The London Care Home Investigation.** *SSRN Electronic Journal.* 2020. [Publisher Full Text](#)
  38. Wang Y, Zhang L, Sang L, *et al.*: **Kinetics of viral load and antibody response in relation to COVID-19 severity.** *J Clin Invest.* 2020; **130**(10): 5325–5244. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  39. Riley S, Ainslie KE, Eales O, *et al.*: **Community prevalence of SARS-CoV-2 virus in England during May 2020: REACT study.** *medRxiv.* 2020. [Publisher Full Text](#)
  40. La Scola B, Le Bideau M, Andreani J, *et al.*: **Viral RNA load as determined by cell culture as a management tool for discharge of SARS-CoV-2 patients from infectious disease wards.** *Eur J Clin Microbiol Infect Dis.* 2020; **39**(6): 1059–61. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  41. Patrozou E, Mermel LA: **Does influenza transmission occur from asymptomatic infection or prior to symptom onset?** *Public Health Rep.* 2009; **124**(2): 193–6. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  42. Spinato G, Fabbris C, Polesel J, *et al.*: **Alterations in Smell or Taste in Mildly Symptomatic Outpatients With SARS-CoV-2 Infection.** *JAMA.* 2020; **323**(20): 2089–2090. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  43. Eliezer M, Hautefort C, Hamel AL, *et al.*: **Sudden and Complete Olfactory Loss of Function as a Possible Symptom of COVID-19.** *JAMA Otolaryngol Head Neck Surg.* 2020; **146**(7): 674–675. [PubMed Abstract](#) | [Publisher Full Text](#)
  44. Menni C, Valdes AM, Freidin MB, *et al.*: **Real-time tracking of self-reported symptoms to predict potential COVID-19.** *Nat Med.* 2020; **26**(7): 1037–1040. [PubMed Abstract](#) | [Publisher Full Text](#)
  45. Leung NHL, Xu C, Ip DKM, *et al.*: **Review Article: The Fraction of Influenza Virus Infections That Are Asymptomatic: A Systematic Review and Meta-analysis.** *Epidemiology.* 2015; **26**(6): 862–72. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  46. Winter AK, Hegde ST: **The important role of serology for COVID-19 control.** *Lancet Infect Dis.* 2020; **20**(7): 758–759. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  47. Beale S, Hayward A, Shallcross L, *et al.*: **A Rapid Review and Meta-Analysis of the Asymptomatic Proportion of PCR-Confirmed SARS-CoV-2 Infections in Community Settings.** University College London. Dataset. 2020. <http://www.doi.org/10.5522/04/12344135.v3>