



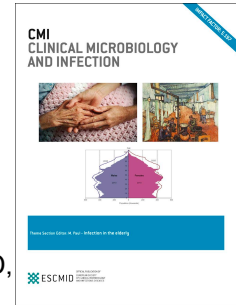
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Journal Pre-proof

Defining the role of asymptomatic and pre-symptomatic SARS-CoV-2 transmission – a living systematic review

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1 **Defining the role of asymptomatic and pre-symptomatic SARS-CoV-2**
2 **transmission – a living systematic review**

3

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27 **Key words:** COVID-19, asymptomatic, transmission, SARS-CoV-2, secondary attack rate

28 **Abstract:**

29 **Background** Reports suggest that asymptomatic individuals (those with no symptoms at all
30 throughout infection) with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are
31 infectious, but the extent of transmission based on symptom status requires further study.

32 **Purpose** This living review aims to critically appraise available data about secondary attack rates
33 from people with asymptomatic, pre-symptomatic and symptomatic SARS-CoV-2 infection.

34 **Data sources** Medline, EMBASE, China Academic Journals full-text database (CNKI), and pre-
35 print servers were searched from 30 December 2019 to 3 July 2020 using relevant MESH terms.

36 **Study selection** Studies that report on contact tracing of index cases with SARS-CoV-2 infection
37 in either English or Chinese were included.

38 **Data extraction** Two authors independently extracted data and assessed study quality and risk
39 of bias. We calculated the secondary attack rate as the number of contacts with SARS-CoV-2,
40 divided by the number of contacts tested.

41 **Data synthesis** Of 927 studies identified, 80 were included. Summary secondary attack rate
42 estimates were 1% (95% CI: 0%-2%) with a prediction interval of 0-10% for asymptomatic index
43 cases in 10 studies, 7% (95% CI: 3%-11%) with a prediction interval of 1- 40% for pre-
44 symptomatic cases in 11 studies and 6% (95% CI: 5%-8%) with a prediction interval of 5- 38%
45 for symptomatic index cases in 40 studies. The highest secondary attack rates were found in
46 contacts who lived in the same household as the index case. Other activities associated with
47 transmission were group activities such as sharing meals or playing board games with the index
48 case, regardless of the disease status of the index case.

49 **Limitations** We excluded some studies because the index case or number of contacts were
50 unclear.

51 **Conclusion** Asymptomatic patients can transmit SARS-CoV-2 to others, but our findings
52 indicate that such individuals are responsible for fewer secondary infections than people with
53 symptoms.

54 **Systematic review registration** PROSPERO CRD42020188168

55 **Funding:** No funding was received

56

57

58 Introduction:

59 Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) demonstrates efficient
60 transmission in populations without effective public health interventions; basic reproduction
61 numbers (R_0) values range between 2-3 [1]. While asymptomatic transmission has been
62 described as the “Achilles’ heel” of control efforts during this pandemic, the extent to which
63 transmission of SARS-CoV-2 by people without symptoms drives this pandemic remains
64 uncertain [2]. SARS-CoV-2 infection that is asymptomatic at the time of laboratory testing is
65 widely reported [3]; however, studies that follow infected people over time suggest that many
66 infections are not asymptomatic throughout the entire disease course, and a large proportion of
67 these individuals ultimately develop a diverse range of symptoms [4-7]. For instance, Sugano et
68 al. reported a detailed cluster outbreak in music clubs in Japan, where asymptomatic cases
69 reported also included pre-symptomatic cases [8]. A living systematic review of studies published
70 up to 10 June 2020 estimated that 20% (95% CI 17 to 25%) of people who become infected with
71 SARS-CoV-2 remain asymptomatic throughout infection [7].

72 One of the barriers to understanding the role of asymptomatic transmission is the lack of
73 consistency in case definitions [9]. While symptom severity exists on a spectrum, individuals
74 infected with SARS-CoV-2 can be miscategorized as asymptomatic, when they have milder or
75 atypical symptoms leading to overestimation of the proportion without symptoms [3, 10]. For
76 instance, in a detailed study of SARS-CoV-2 infections in Iceland where individuals deemed at
77 high risk for COVID-19 including those with a consistent syndrome were screened in a targeted
78 manner, and other individuals were tested via a population screening mechanism, more than a
79 third in the second group reported symptoms potentially consistent with COVID-19 [3]. However,
80 it is increasingly becoming clear that some individuals experience more diverse symptoms,
81 including taste and smell disturbance or myalgia, either for the entire course of illness or
82 preceding respiratory symptoms. These symptoms can be so mild and insidious that they do not
83 limit patients’ daily activities [4, 11]. The situation is further complicated by subjective patient
84 perception and differences between studies in the elicitation and reporting of symptoms.

85 There are reports describing asymptomatic individuals with SARS-CoV-2 who are infectious [12]
86 and who have infected one or more contacts [13], but the extent and significance of
87 asymptomatic transmission requires further understanding. The aim of this review is to
88 summarize the available evidence about secondary attack rates (defined as the probability that
89 an infected individual will transmit the disease to a susceptible individual) amongst the contacts
90 of individuals with SARS-CoV-2 with different symptom status to provide information about how
91 contagious they are, and their role in driving the pandemic.

92

93 **Methods:**

94 Systematic review was registered in PROSPERO on 8 June 2020 (CRD42020188168) and will
95 be updated 4-6 months according to the availability of new evidence as a living systematic
96 review [14]. The larger review aims to answer transmission dynamics of SARS-CoV-2. The
97 analysis in this report addresses one of the review questions; to identify secondary attack rate
98 based on symptom status.

99

100 **Definitions**

101 We defined “asymptomatic” as an individual with laboratory-confirmed SARS-CoV-2 infection but
102 without symptoms throughout their entire course of infection, or after 14 days of follow up;
103 “paucisymptomatic” as an individual with laboratory-confirmed SARS-CoV-2 infection with mild
104 symptoms, and “pre-symptomatic” as an individual who reports no symptoms at the time of the
105 initial positive test result, but who subsequently develops symptoms attributable to COVID-19.
106 We used these definitions to categorize the index cases. Secondary attack rate was defined as
107 the number of new SARS-CoV-2 infection cases among susceptible contacts of primary cases
108 divided by the total number of susceptible contacts.

109

110 **Search Strategy**

111 We retrieved articles about transmission of SARS-CoV-2 infection through systematic searches
112 of eight databases: Medline, EMBASE, Europe PMC, Web of Science, SCOPUS, Chinese
113 database (CNKI), and preprint servers (MedRxiv, BioRxiv) using relevant Medical Subject

114 Headings (MeSH) terms (Supplementary material). The initial search was completed from 30
115 December 2019 to 21 May 2020, searches were repeated on 8 June 2020 and 3 July 2020,
116 owing to the rapidly increasing numbers of studies.

117

118 **Study Selection**

119 Studies were eligible if they met the inclusion criteria: (1) report on Coronavirus disease 2019
120 (COVID-19) or SARS-CoV-2 infection and (2) report an outbreak investigation or contact tracing
121 study. Exclusion criteria were: (1) review articles; (2) observational studies providing only the
122 proportion of individuals infected; (3) studies that do not indicate the number of contacts or
123 secondary infections; and (4) reports in media sources. We also manually screened the
124 references of the included original studies and reviews to identify additional eligible studies.

125

126 **Data Extraction**

127 Two authors (XQ and AIN) independently reviewed reports by title and abstract for relevance,
128 with at least 20% of all reports being screened in duplicate to ensure consistency. Two authors
129 then independently read the full text report of all studies not excluded by title and abstract, to
130 consider eligibility for inclusion. Any disagreements regarding study inclusion were resolved
131 through discussion with a third author (MC). Data were extracted onto a standardized form. From
132 each study, the following variables were extracted: the name of the first author, year of
133 publication, country, sample size, details of index cases (categorised as asymptomatic, pre-
134 symptomatic and symptomatic); event details such as environment, transmission details; number
135 of contacts, number of secondary cases. If these data were not reported, we contacted authors
136 to request them and checked with the authors about all symptoms that they sought.

137

138 **Risk of bias in included studies**

139 Two authors (XQ and AIN) independently assessed completeness of reporting and risks of bias,
140 using an adapted version of the Joanna Briggs Institute Critical Appraisal Checklist for Case
141 Series (Supplementary material). Any disagreements were resolved through discussion with a
142 third author (MC).

143

144 **Data synthesis and statistical analysis**

145 The studies are summarized in text and table form, descriptive statistics were completed for key
146 outcome measures. Secondary attack rates were computed from raw data in each study, dividing
147 the number of infected contacts of primary cases by the total number of susceptible exposed
148 contacts. A pooled analysis was carried out to generate summary estimates for the secondary
149 attack rate in each subgroup analyzed (asymptomatic, pre-symptomatic and symptomatic index
150 cases), in the framework of a random effect model. The Freeman – Tukey double-arcsine
151 variance-stabilizing transformation was used to combine data, due to its advantage over log and
152 logit transformations which did not allow to compute the proportion in the presence of zero event
153 counts [15]. Secondary attack rates are presented as a proportion along with 95% CIs in forest
154 plots. Heterogeneity between study estimates was gauged by means of the Cochran's Q and I^2
155 statistic: an I^2 value above 75% indicates high heterogeneity [16]. Moreover, a 95% prediction
156 interval is displayed in the forest plots, which is an index of dispersion, providing information on
157 how widely the true effect size varies. It can also provide the range of values in which a future
158 observation will fall [17]. Analyses were performed through the software MetaXL version 5.3
159 (Ersatz, EpiGear International, Sunrise Beach, Australia) [18].

160

161 **Results:**

162 The systematic search identified 927 potentially relevant articles and 789 records were screened
163 after removal of duplicates. Of 187 articles retrieved for full-text review and assessed for
164 eligibility, 80 studies were included in the systematic review, and among those we identified 69
165 studies that indicated the symptom status of index case(s). In this analysis, we excluded 11
166 studies that reported asymptomatic and symptomatic index cases together or no symptom status
167 of the index case was available. We re-classified three studies from asymptomatic to pre-
168 symptomatic as the index cases developed symptoms later during the disease course after
169 reviewing the details and contacting the authors [19-21]. The number of selected papers at each
170 step of the screening and eligibility are reported in the flow diagram (Figure 1).

171

172 Summary of secondary attack rates of asymptomatic index cases

173 Ten studies were included in the quantitative analysis (Table 1) [6, 13, 22-29]. Summary
174 secondary attack rate estimate was 1% (95% CI: 0%-2%) with a prediction interval ranged of 0-
175 10% (Figure 2). All except one tested all close contacts for SARS-CoV-2, regardless of
176 symptoms [26]. Cheng et al. only tested symptomatic cases, but they also tested high risk
177 populations regardless of symptoms including the household and hospital contacts [26]. Six
178 studies reported on household contacts, two studies included hospital contacts and two studies
179 included non-household close contacts.

180

181 Three studies identified no secondary cases after following up 17, 91 and 455 close contacts of
182 asymptomatic index cases (asymptomatic secondary attack rate of 0%) [24-26]. Of those, two
183 studies demonstrated higher symptomatic secondary attack rates; Cheng et al. demonstrated
184 that mild cases had a secondary attack rate of 3.8% (95% CI 1.1, 12.8%) and severe cases had
185 4% (95% CI 1.0, 15.8%) secondary attack rate [26], while Park et al. showing household
186 symptomatic secondary attack rate of 16.2% (95% CI 11.6, 22.0%) [24]. In another study, 305
187 contacts of 8 asymptomatic cases were followed up, identifying one secondary case (secondary
188 attack rate 0.3% (95% CI 0.0, 1.8%) [28]. In the same study, attack rates from index cases with
189 mild, moderate and severe diseases were 3.3%, 5.6% and 6.2%, respectively. Zhang et al.
190 followed up 119 close contacts of 12 asymptomatic index cases and identified one secondary
191 case, an asymptomatic secondary attack rate of 0.8% (95% CI 0.0, 4.6). In the same study, the
192 secondary attack rate was 3.5% (95% CI 1.5-8.0) for those with mild, 5.7% (95% CI 2.5, 12.8%)
193 for those with moderate, and 4.5% (95% CI 0.8, 21.8%) for those with severe symptoms [6]. In
194 this study, close contacts that lived with an index case had 12 times the risk of infection as those
195 who did not live with the index case (RR 12.5 - 95% CI 1.6, 100.8) and those who had frequent
196 contact with an index case-patient, and those who had more than 5 contacts had 29 times the
197 risk of infection as those with fewer contacts (RR 29.0 - 95% CI 3.6, 232.3). Two studies
198 indicated an asymptomatic secondary attack rate of 1% and 1.9% [22, 23]. Chaw et al. reported
199 asymptomatic and pre-symptomatic contacts together. The authors clarified that 3 asymptomatic
200 index cases and their 106 close contacts were followed up, leading to 3 secondary cases, a

201 secondary attack rate of 2.8% (95% CI 0.06, 8.0%). In this study, the overall secondary attack
202 rate was 10.6% in the household setting, which was higher for symptomatic cases (14.4%, 95%
203 CI 8.8, 19.9%) than that of asymptomatic cases and for non-household contacts 0.7 (95% CI 0.1,
204 1.3) [13]. Zeng et al. conducted the largest contact tracing study, following up 753 close contacts
205 of asymptomatic index cases and identified one secondary case, an asymptomatic secondary
206 attack rate of 0.13% (95% CI 0.0, 0.7%) [27].

207

208 **Summary of pre-symptomatic secondary attack rates**

209 Sixteen papers reported either outbreak investigations or contact tracing studies reporting
210 transmission from an index case during the pre-symptomatic period [13, 19, 21, 26, 30-40]
211 (Table 2). Of those, eleven studies were included in the quantitative analysis. The summary SAR
212 estimate was 7% (95% CI: 3%-11%) with a prediction interval of 1 to 40% (Figure 3). These
213 studies followed up 22 to 585 close contacts whose initial exposure occurred before symptom
214 onset of the index case. Even in studies that followed up large numbers of people, including
215 community contacts, the majority of secondary cases identified were from the same household or
216 among friend gatherings. In these studies, having meals together, or playing cards with the index
217 case were exposure activities associated with transmission. The remaining one study reported
218 an outbreak in a restaurant [40] and four studies exclusively reported family cluster outbreaks
219 [30, 32, 33, 39]; these investigations did not test contacts outside the household, and it is
220 challenging to truly differentiate transmission during the pre-symptomatic period from
221 symptomatic transmission in the household setting (Supplementary Figure 1).

222

223 **Summary of symptomatic secondary attack rates**

224 Forty-six papers reported either outbreak investigations or contact tracing studies reporting
225 transmission from symptomatic index case(s). Of those, 40 reported contact tracing studies
226 reported secondary attack rates ranging from 0% to 38.89% [13, 24, 27, 28, 38, 41-75] and 6
227 reported outbreak investigation [76-80] (Supplementary Table 1). 40 contact tracing studies with
228 44 observations were included in the quantitative analysis (Figure 4). The summary estimate of
229 SAR from symptomatic index subjects was 6% (95% CI: 5%-8%) with a prediction interval of 5-

230 38%. Of those, 9 studies reported less than 1% secondary attack rates, 2 of those were in
231 healthcare setting, 2 included outdoor interaction, 4 included non-household contacts. Higher
232 frequency of contacts and household contacts were reported to be higher risk than non-
233 household contacts.

234

235 **Quality assessment**

236 All papers included a clear definition of symptomatic and asymptomatic cases, number of
237 secondary cases and number of contacts. The majority of studies identified index cases with a
238 clear diagnosis, had an acceptable case definition and sufficiently followed up close contacts (for
239 a minimum of 14 days). However, in some studies the definition of close contact and setting of
240 transmission was not provided. In addition, it was unclear in four reports whether all potential
241 close contacts were included, therefore, the direction of bias is uncertain. We summarized the
242 quality assessment in Supplementary Table 2.

243

244 **Discussion:**

245 This systematic review provides comprehensive data on secondary attack rates based on
246 symptom status of the index case(s). While asymptomatic patients can transmit the virus to
247 others [81], the findings from ten studies in this review found summary secondary attack rates of
248 1% with a prediction interval of 0-10% for asymptomatic index cases compared with secondary
249 attack rates of 6% with a prediction interval of 5-38% in symptomatic cases and 7% with a
250 prediction interval of 1-40% in pre-symptomatic case. These findings suggest that individuals
251 who are asymptomatic throughout the disease course are responsible for fewer secondary
252 infections than symptomatic and pre-symptomatic cases. Most transmission events were
253 associated with living with the index case or group activities such as sharing meals and playing
254 board games.

255

256 Given the importance of transmission heterogeneity in propagating the pandemic, it is important
257 that we learn about the various factors that contribute to transmission. According to modelling
258 and contact tracing studies, around 80% of secondary infections can be linked to 20% of cases

259 which distinguishes SARS-CoV-2 from seasonal influenza, although a similar pattern was also
260 observed in SARS-CoV and MERS-CoV [82-84]. While there are multiple factors (environmental
261 factors, contact patterns and socioeconomic inequalities) that contribute to this heterogeneity,
262 some evidence starting to emerge about the influence of individual's infectiousness on
263 transmission dynamics. In this systematic review, we found that index cases with symptoms had
264 a higher secondary attack rate compared with truly asymptomatic index cases. While there is a
265 need to better understand this difference, it may be due to shorter duration of infectiousness. In a
266 living systematic review including of studies published up to 6 June 2020, we found that cases
267 with asymptomatic people had a shorter duration of RNA shedding than symptomatic individuals
268 [85]. Asymptomatic patients may therefore be contagious but for a shorter duration than
269 symptomatic people; this might contribute to lower transmission to their contacts. However, we
270 do not yet know the relative importance of behavioral factors by the host versus environmental
271 factors in determining transmission risk. It is not known whether the size of the cluster of
272 secondary infections would be different according to index case symptom status in a high-risk
273 environment with no mitigation measures in place.

274

275 Modelling studies suggest that it is not possible to have widespread infection without substantial
276 pre-symptomatic transmission. Viral load dynamics of SARS-CoV-2 derived from confirmed
277 cases suggest that peak viral loads are detected at the start of symptom onset up to day 5 of
278 illness, indicating highest infectiousness occurs just before or within the first few days after
279 symptom onset [85]. So far, several contact tracing studies emphasize that the highest risk of
280 transmission occurs during the prodromal phase or early in the disease course [64, 86]. For
281 instance, in a prospective contact tracing study of 100 confirmed cases of COVID-19 and 2761
282 close contacts, no secondary cases were identified when the exposure occurred more than 5
283 days after the symptom onset [26]. Our findings therefore have important implications from a
284 public health perspective. In settings such as nursing homes, homeless shelters, prisons, cruise
285 ships and meat-packing plants in which many people spend prolong period of time together in
286 the same environment including sleeping, dining and sharing common facilities, and where
287 several outbreaks have been documented, pre-symptomatic transmission may contribute

288 substantially to transmission [87, 88]. In these settings, when infection develops, most patients
289 are already inside the facility with high viral loads that increase the risk of onward transmission.
290 This highlights the importance of mitigation measures and surveillance in these settings to
291 identify those patients early in the disease course to prevent onward transmission inside the
292 facility.

293

294 This systematic review has several strengths. Firstly, this is a living systematic review examining
295 the transmission of SARS-CoV-2 through contact tracing and outbreak investigation studies.
296 Secondly, we only included studies with clear case definitions, which indicated the number of
297 contacts and secondary cases. We excluded studies in which the index case was unclear, or the
298 numbers of contacts were not provided. The estimates from individual studies are also subject to
299 limitations, such as imprecision resulting from small study size, and multiple sources of bias in
300 the estimation of the true secondary attack rate, which are detailed in this paper [89]. Moreover,
301 while the number of index cases could influence the confidence interval estimation for secondary
302 attack rate due to heterogeneity among index cases, we have constructed a prediction interval to
303 yield conservative confidence interval estimates.

304

305 We identified two other systematic reviews that investigated asymptomatic transmission, with
306 different research questions, which results in different search terms and studies retrieved. One
307 living systematic review, which included studies published up to 10 June 2020, identified five
308 studies that directly compared secondary attack rates between asymptomatic and symptomatic
309 index cases; all were included in our review [7]. This study only included studies that provided
310 data to allow relative risks to be estimated. The summary risk ratios for asymptomatic versus
311 symptomatic (0.35, 95% CI 0.10, 1.27) and pre-symptomatic versus symptomatic (0.63, 95% CI
312 0.18, 2.26) are consistent with our findings. The second review estimated only household
313 secondary attack rates and included studies published up to 29 July 2020 [90]. Of three studies
314 that included asymptomatic index cases, two were included in our review. We excluded one of
315 the studies because the number of contacts of asymptomatic index cases was not specified; we
316 have not yet received details of the study after contacting the authors. Advantages of our review

317 over these two studies are inclusion of studies published in Chinese, search terms that aimed to
318 capture studies specifically estimating secondary attack rates.

319

320 In summary, whilst asymptomatic transmission is a major concern for SARS-CoV-2 community
321 spread, secondary attack rates from those who remain asymptomatic throughout their course of
322 infection are low suggesting limited infectiousness. Although it is difficult to estimate the
323 proportion of pre-symptomatic transmission, these patients are likely to be highly infectious just
324 before and around the time of symptom onset and appear to transmit efficiently, particularly
325 within households. Given these results, in the context of limited resources, approaches should be
326 targeted predominantly on identifying and immediately isolating patients with prodromal or mild
327 symptoms and their contacts, which may avert a significant number of community transmission
328 clusters [91]. Future clinical studies should incorporate clear definitions and assess a broad
329 range of symptoms associated with COVID-19, include longitudinal follow up of patients, and
330 calculate secondary attack rates for a wider range of settings and populations [9].

331

332 **Conflict of Interest:** The authors declare that there is no conflict of interest

333

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335

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340 searching and downloading Chinese database for this review.

341

342 **Contribution statement:**

343 X Qiu: investigation, data curation, writing – original draft; A Nergiz: investigation, data curation,
344 writing – review and editing; A. E. Maraolo: methodology, formal analysis, writing – original draft;

345 I. Bogoch and N. Low: interpretation, writing – review and editing; M. Cevik: conceptualisation,
346 methodology, investigation, writing – original draft, supervision.

347

348

349 **Figure legends:**

350 **Figure 1: Flowchart describing the study design process**

351 **Figure 2: Secondary attack rates from asymptomatic index cases to their contacts**

352 **Figure 3: Secondary attack rates from pre-symptomatic index cases to their contacts**

353 **Figure 4: Secondary attack rates from symptomatic index cases to their contacts**

Journal Pre-proof

Transmission dynamics and secondary attack rates

354 Table 1: Transmission from truly asymptomatic index cases

	Index Cases	Environment	Number of contacts	Number of Secondary cases	Asymptomatic SAR (95% CI)	Symptomatic SAR (95% CI)
Chaw et al. * [13]	3	Household	106	3	2.8% (0.06, 8.0)	14.4% (8.8, 19.9)
		Non-household				0.7% (0.01, 1.3)
Chen Y et al. [29]	30	Household	146	6	4.1% (1.7, 9.1)	6.3% (5.3, 7.5)
		Non-household				
Cheng et al.[26]	9	Non-household	91	0	0% (0.0, 4.1)	Mild 3.76 (1.1-12.8) Severe 3.99 (1.0-15.8)
Gao et al.[25]	1	Household and healthcare	455	0	0% (0.0, 0.08)	
Jiang et al.[22]	3	Household	195	2	1% (0.1, 3.7)	
Luo et al. [28]	8	Household and non-household	305	1	0.33% (0.0, 1.8) OR (0.29 (0.04, 2.2))	Mild 3.3% (OR 0.48 (0.28, 0.82)) Mod 5.6% (OR 1.0) Sev 6.2% (OR 1.19 (0.7, 2.1))
Mandić-Rajčević et al.[23]	1	Healthcare	53	1	1.9% (0.0,10.0)	
Park et al.[24]	4	Household	17	0	0% (0.0, 19.5)	16.2 % (11.6,22.0)
Zeng et al. [27]		All contacts	753	1	0.13% (0.0, 0.7)	2.02% (1.8, 2.3)
Zhang et al.[6]	12	Household	119	1	0.8% (0.0, 4.6)	Mild 3.5% (1.5, 8.0) Mod 5.7% (2.5, 12.8) Severe 4.5% (0.8, 21.8)

Transmission dynamics and secondary attack rates

355 Abbreviations: CI, confidence interval; OR, odds ratio; SAR, secondary attack rate; sev, severe * authors contacted for more details

Index Cases	Environment	Number of contacts	Number of Secondary cases	Pre-symptomatic SAR (95% CI)	Secondary cases
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Journal Pre-proof

356 **Table 2: Transmission during pre-symptomatic period**

Transmission dynamics and secondary attack rates

Contract-tracing						
Chaw et al.* [13]	7	Household and non-household	585	15	2.56% (1.4, 4.2)	
Cheng et al.[26]	NR	Household and non-household	299	2	0.7% (0.1, 2.4)	
Hong L et al.[31]	41	Household and non-household	197	24	12.2% (8.0, 17.6)	Friends, family, card playing partners
Huang et al.[19]	1	Friends	22	7	31.8% (13.0, 54.9)	Shared meal with index
Pang et al. [34]	1	Household and non-household	103	6	5.8% (2.2, 12.2)	Living together or sharing meal
Park et al. [24]	4	Household	11	0	0% (0.0, 2.8)	
Pung R et al. [38]	2	Religious gathering	142	3	2.1% (0.5, 6.5)	
Qian et al. [35]	1	Household and non-household	137	10	7.3% (3.6, 13.0)	Living together or sharing meal
Yang et al. [36]	2	Household and non-household	123	6	4.9% (1.8, 10.3)	All secondary cases lived together
Ye et al. [21]	1	Family	44	4	9.1% (2.5, 21.4)	Extended family
Zhao et al [37]	1	Friends	15	4	26.7% (7.8, 55.1)	Meal and Mahjong game gathering
Outbreak investigation						
Chen M et al.[30]	1	Household	3	2	66.7% (9.4, 99.2)	Family cluster outbreak
Li P et al.[32]	1	Household	5	4	80% (28.4, 99.5)	Family cluster outbreak
Lu J et al [40]	1	Restaurant	82	9	11% (5.9, 19.6)	
Jiang Y et al [39]	1	Household	7	3	42.9% (11.8, 79.8)	Family cluster outbreak
Qian G et al. [33]	2	Household	4	3	75% (10.4, 99.4)	Family cluster outbreak

Transmission dynamics and secondary attack rates

357 Abbreviations: CI, confidence interval; SAR, secondary attack rate

358 * authors contacted for more details

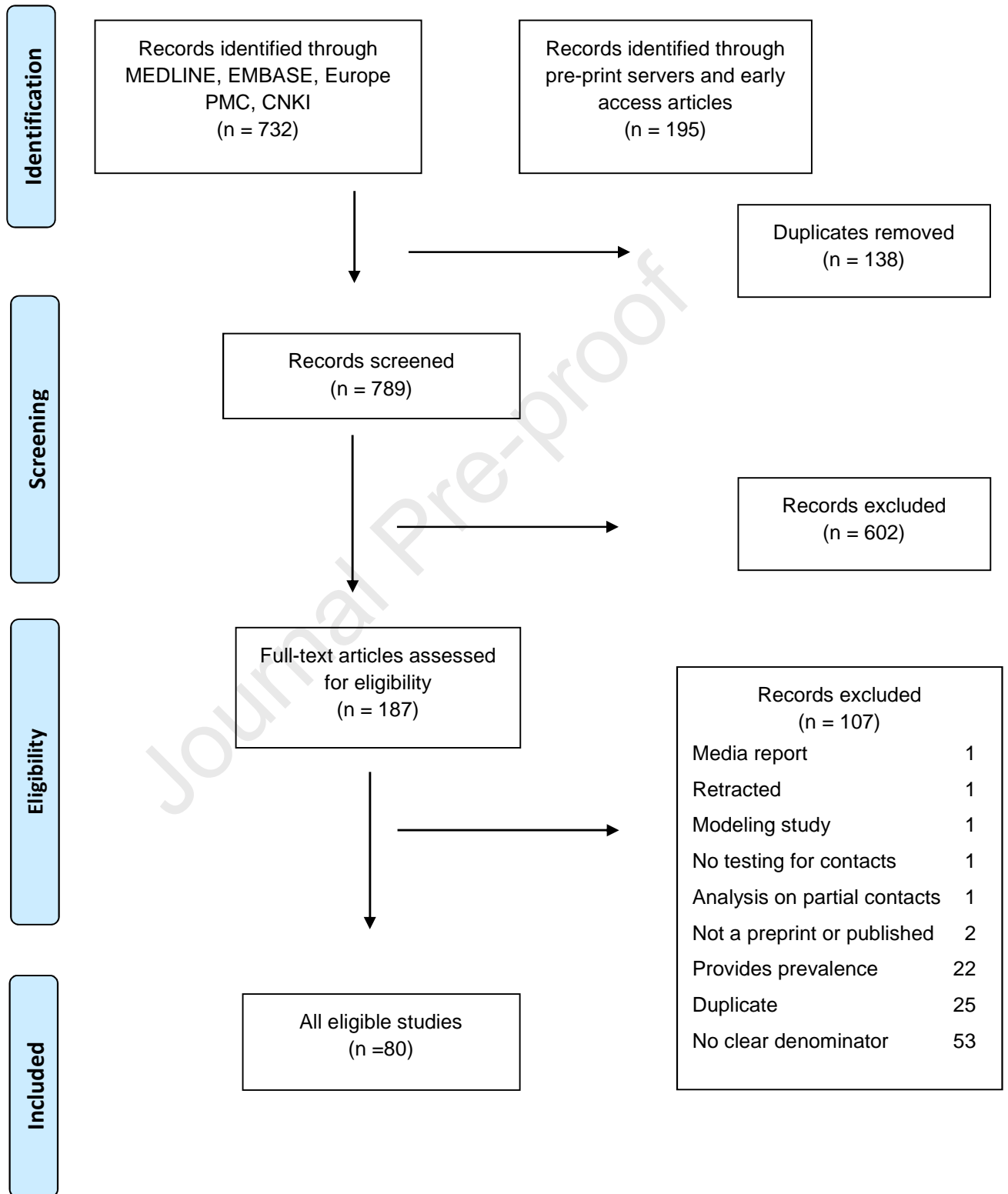
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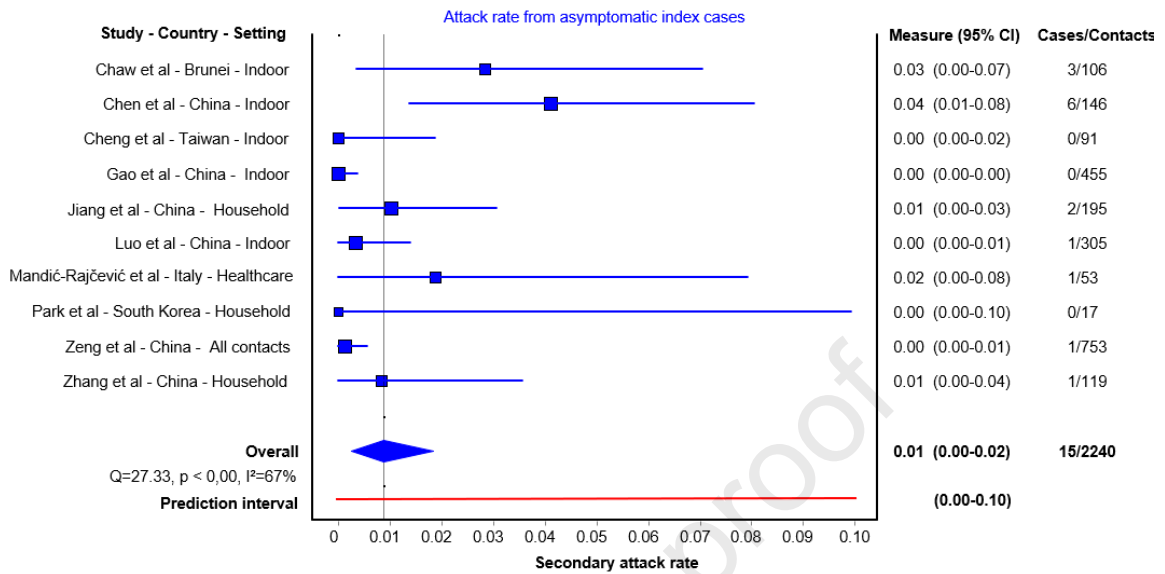
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Figure 1. Flowchart describing inclusion and exclusion of studies at each stage of the review



410 **Figure 2: Secondary attack rates from asymptomatic index cases to their contacts**

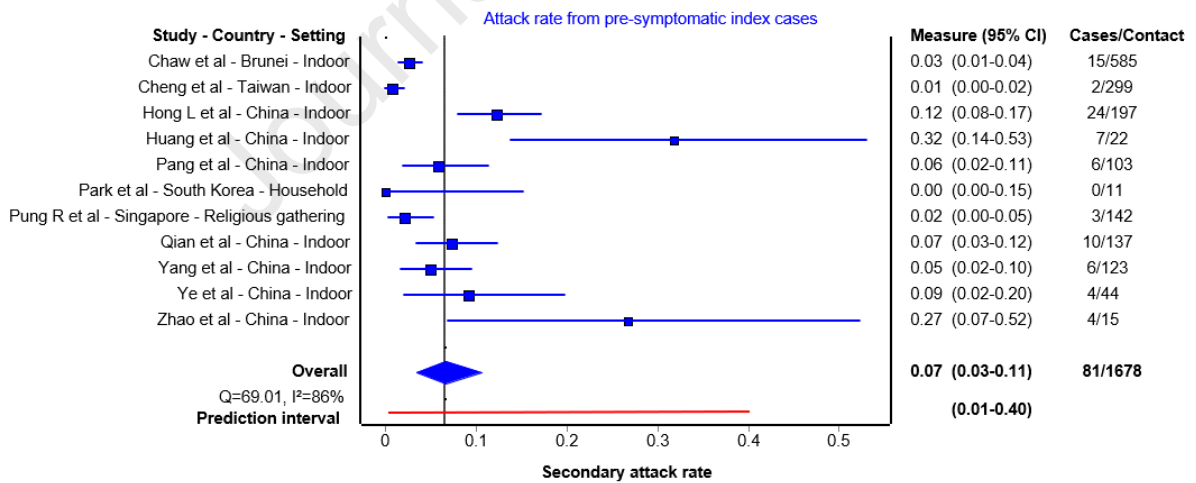
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414 For each study the secondary attack rate is reported with its 95% CI.
415 A prediction interval at the bottom of the forest is depicted.

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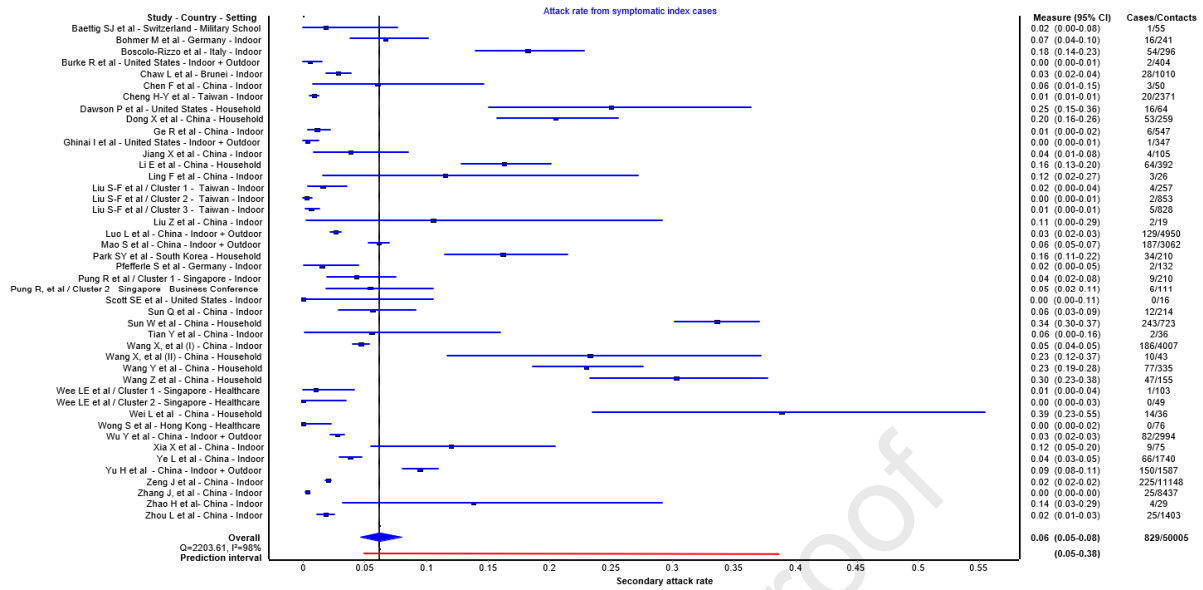
Figure 3: Secondary attack rates from pre-symptomatic index cases to their contacts



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422 For each study the secondary attack rate is reported with its 95% CI.
423 A prediction interval at the bottom of the forest is depicted.

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428 **Figure 4: Secondary attack rates from symptomatic index cases to their contacts**



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430 For each study the secondary attack rate is reported with its 95% CI.
 431 A prediction interval at the bottom of the forest is depicted.

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