International Journal of Research in Medical Sciences
Bardhar S et al. Int J Res Med Sci. 2022 Aug;10(8):1737-1746
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20221988

Systematic Review

The secondary attack rate (SAR) of SARS-CoV-2 in households: a systematic review

Shubhra Bardhar*, Anoop Khanna

Department of Public Health, Johns Hopkins Bloomberg School of Public Health, USA and IIHMR University, Jaipur, India

Received: 06 January 2022
Revised: 29 June 2022
Accepted: 13 July 2022

***Correspondence:**
Dr. Shubhra Bardhar,
E-mail: shubhrabardhar12@gmail.com

ABSTRACT

Households are considered an essential setting for SARS-CoV-2 transmission due to the high intensity and frequency of interaction among family members. Many reports have suggested the high transmission risk of coronavirus disease-2019 in contacts within a household. Transmission parameter such as secondary attack rate is a helpful indicator used for assessing the risk of transmission in the household environment. The systematic review was done based on recommended guidelines of PRISMA for reporting. Three databases namely "Pubmed," "Embase," and "Web of science" were utilized for retrieving the articles. Each included study was evaluated based on the following criteria: study title, duration of the study, location, authors, design of the study, type and number of index cases, percentage of SAR, the number of contacts within the household, and other key findings. On the selection basis, 26 articles were included in the study reporting secondary attack rates in different countries. The majority of the studies reported household secondary attack rates to be higher among household adults and the old age group compared to children, SAR was also greater in spouses compared to other categories of household contact and females had slightly higher SAR compared to males. Often contact with index cases and symptomatic index cases increased the risk of SAR. Thus, this systematic study confirms that households have a significant role in the spread or transmission of SARS-CoV-2.

Keywords: SARS-CoV-2, COVID-19, Household contacts, Secondary attack rate, Secondary transmission, Household transmission

INTRODUCTION

The novel coronavirus disease of 2019 or the COVID-19 pandemic, caused by SARS-CoV-2 ("severe acute respiratory syndrome coronavirus 2"), has turned into a public-health crisis of global concern.[1] It started in December 2019 with a few unknown incidents of pneumonia in China (Wuhan) and then began to spread very rapidly to several other nations.[1] Following the spread within a few months COVID-19 or the coronavirus disease was declared a pandemic on March 11th, 2020 by WHO.[1] Globally, there have been 239,437,517 confirmed cases and 4,879,235 deaths related to COVID-19 as of 15th October 2021(WHO).[2] India stands second in the highest number of cases with 34,037,592 confirmed cases as of 15th October 2021.[2]

The disease spreads by direct contact with the respiratory droplets of a COVID-19 infected person, generated through coughing and sneezing. Individuals can also get infected by contacting virus-infested surfaces and then touching their facial regions such as eyes, mouth, and nose.[3] Disrupting the chain of person-to-person transmission through isolation/quarantine of the cases and contact-tracing has a key role in preventing this disease.[4] Research on household transmission is a necessary step in understanding the emerging pandemic virus as there is a large pool of exposed and susceptible individuals.[4]

Household is an appropriate setting for determining person-to-person COVID-19 transmission and also to characterize factors causing infectivity.[4]

Because of the high frequency and intensity of interaction among family members, households are considered an essential unit in COVID 19 transmission.[4] Many reports have suggested the higher risk of transmission of SARS-CoV-2 in contacts occurring within households. According to the joint mission of WHO (China) on COVID-19, the most epidemiologically related clusters were households in China and it was emphasized that research on the risk factors for transmission within households should be prioritized.[5] As there are many confirmed case clusters from households, transmission occurring inside homes has become an essential aspect of coronavirus disease-19 spread.[6] Transmission parameter such as secondary attack rate is a helpful indicator used for assessing the risk of transmission in the household environment. A study conducted in Qingdao Municipal, China found a SAR (secondary attack rate) of 17.9% in household contacts, a similar result was observed in another research conducted in China, Hubei where SAR was 16.3%.[7]

Pucharoen et al did a statistical analysis from contact-tracing data in Thailand and supported the evidence for SARS-CoV-2 household transmission[7]. Similar results were revealed in other studies done in California, Illinois, and Westchester, which recorded a significantly high chance of transmission between spouses.[7,8] According to Dr. Ryan (executive-director of WHO health emergency division), the majority of the secondary cases occur within families and this has been driving the epidemic.[8]

In epidemiology, the secondary attack rate in households is determined by "dividing the total number of infected household cases resulting from exposure to an index case during the incubation period by the total number of susceptible household contacts".[9] The main target of this systematic research is to understand and outline the global data on the Secondary Attack Rate of SARS CoV-2 in contacts occurring in household settings and also to identify the factors, transmission elements, and other characteristics across different countries.

Rationale of the study

Protective measures such as social distancing and face masks use have shown to be useful in decreasing the transmission of SARS-CoV-2.[10] Such interventions, however, may be difficult to apply within families, where the spread of the disease remains a significant issue.[10] A lot of uncertainty remains about household transmission and factors that may affect it. Household transmission is not looked upon properly despite the significance of these interactions in the spread of the coronavirus disease and evaluating the usefulness of mitigation efforts.[10]

Very few studies have been conducted regarding household transmission. This systematic review aims to understand the transmission dynamics using SAR within households. As the number of susceptible and exposed persons in a household setting is large, SAR is useful to observe the chains of transmission.[11] Also, understanding the transmission of SARS-CoV-2 in households is essential to guide the public-health policies about quarantine and other measures.[12]

Objectives of the study

The primary objective is to understand and study the secondary attack rate of SARS-CoV-2 disease within household-contacts. The secondary objective is to identify the key elements related to the transmission in household-contacts.

METHODS

The systematic research was done on the basis of recommended PRISMA ("Preferred reporting items for systematic reviews and meta-analysis") guidelines. "The Cochrane Handbook for Systematic Reviews of Interventions" was utilized for systematically designing and conducting the study.

Research technique and keywords

Three databases were utilized namely "EMBASE," "WEB OF SCIENCE," and "PUBMED" for retrieving the articles. Keywords that were used for searching - "Coronavirus" or "SARS-CoV-2" or "COVID-19" AND "Household contacts" AND "Secondary Attack Rate" or "Secondary transmission". All these research terms were used in the same format in all the databases. Additionally, the platform Google Scholar was used with the same keywords for finding the related grey literature and reporting the household Secondary Attack Rate of coronavirus disease.

Inclusion and exclusion criteria

This review included articles published between January 2020 to August 2021 and included only those articles which were published in the English language. Articles not providing quantitative data about the Secondary Attack Rate (SAR) and articles reporting the SAR in all close contacts but not specifically in the contacts within the household were eliminated from this review. We also excluded those articles defining household members as close relatives who did not share the same residence.

Those articles in which SAR was calculated by dividing a total number of cases infected by index case by a total number of susceptible contacts within the households were included in the study and other articles estimating SAR by another method were excluded.

The remaining papers were evaluated for possible inclusion, where articles with inadequate reporting were eliminated.

Articles included

A total of 26 articles were included in the study based on the inclusion and exclusion criteria mentioned above. (FIGURE-1 PRISMA FLOWCHART).

Definition

According to the WHO "a household contact is defined as any person who has resided in the same household (or other closed settings) as a confirmed COVID-19 case".[13] Studies have considered various definitions of household-contacts. For this paper along with the WHO definition of household-contacts these were also considered:"Spent at least one night in the same residence during the presumed infectious period", "Sharing a room, apartment, or other sleeping arrangements".[4,14-16] "Those who lived with primary cases in a house 4 days before and for more than 24 hours after the primary cases developed illness related to COVID-19", "Who lived in the same house of a symptomatic index case up to 4 days before the symptom onset or with an asymptomatic index case up to 4 days prior to the collection date of the first positive test result," "Same residential address,".[16-19] "Those who resided in the same house as the first case from 2 days before symptom onset to isolation".[20] In the studies, the index case was defined as the first case in the household to be confirmed COVID-19 positive or the confirmed COVID-19 positive cases with the earliest symptom onset date.

Data extraction

The study details and database searches results were exported to a Microsoft Excel file, and each included study was evaluated based on the following criteria: study title, duration of the study, location, authors, design of the study, type and number of index cases, number of household-contacts, SAR%, and other key findings. The PRISMA flowchart below depicts the complete screening process and study selection.

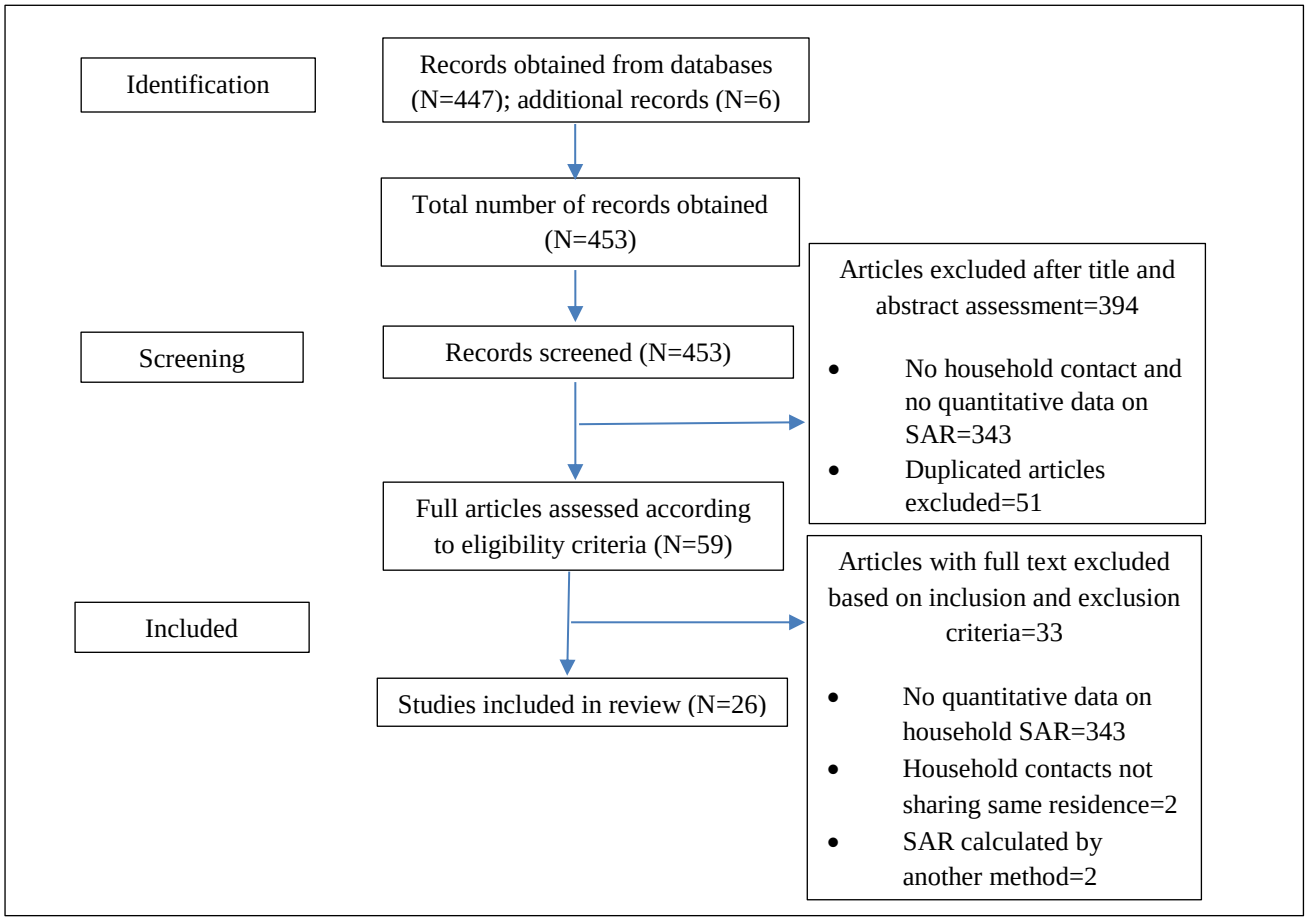

Figure 1: PRISMA flow chart.

Ethical approval

This research is a systematic review based on already published literature. In a systematic review, the data is collected by reviewing systematically the existing information. So, this study did not require any ethical approval. However, care was taken that studies included in the review provided evidence of ethical clearance and informed consent of the cases wherever required.

RESULTS

Characteristics of the study

A total of 453 papers were found in the multiple database search. 394 articles were excluded after the abstract and title assessment. 33 articles were excluded from 59 articles based on the inclusion and exclusion parameters. Finally, 26 articles were included in the study reporting the (SAR) Secondary Attack Rate in different countries. This was achieved through the selection/screening processes presented in the form of a PRISMA diagram. Both retrospective and prospective study designs were used. The number of household-contacts evaluated per study ranged from 15 to 1779 (Table 1). The highest number of studies were found in China (nine) (Table 2) followed by three papers in South Korea, two studies in Japan, the USA and Taiwan. One study in Ireland, Canada, Darussalam, Madagascar, Rwanda, England, Egypt, and Singapore. Household contacts were largely tested regardless of symptoms except for five studies in which only symptomatic household contacts were tested. (Table 2). The confirmation of the index and secondary cases of COVID-19 was based on the diagnostic criteria of that particular nation. However, RT-PCR is a globally accepted method of diagnosis and was utilized in almost all of the papers/studies.

Secondary attack rate (SAR) characteristics in household

Details of the household-contacts Secondary Attack Rate were evaluated from every study and was observed to be in between 2.93% to 89.8% (Table 1). Most of the studies started collecting/reporting data on SAR in January 2020. Some were started in March 2020 and April 2020. Only one study was initiated in August 2020 and ended by February 2021. Most of the studies also included the 95% confidence interval (CI) for SAR (Table 1). According to the following tables SAR was (10.3%-32.4%) in China, (8.2%-15.1%) in South Korea, (2.1%-25.2%) in Japan, (13%-60%) in USA, (4.6%-46.2%) in Taiwan, (15.9%) in Ireland, (14.7%) in Canada, (10.6%) in Darussalam, (43%) in Madagascar, (2.93%) in Rwanda, (33%) in England, (89.8%) in Egypt, (5.9%) in Singapore.

Table 1: SAR within households based on the number of contacts in household and index cases.

S. No.	Author	Enrollment dates	Index cases no.	Household contacts no.	Household SAR% CI 95%
1	Burke et al	January-January 2020	9	15	13 (4-38)
2	Wu et al	January-February 2020	35	148	32.4 (22.4-44.4)
3	Bi et al	January-February 2020	391	--	15.8 (12.9-19.4)
4	Li et al	January-February 2020	105	392	16.3
5	Yi et al	January-February 2020	96	225	42.9
6	Hsu et al	January 2020-February 2021	18	145	46.2
7	Luo et al	January-March 2020	391	1015	10.3 (8.5-12.2)
8	National Emergency Response Center team (COVID-19)	January -March 2020	30	119	7.56 (3.7-14.26)
9	Zhang et al	January-March 2020	359	62	16.1 (9.0-27.2)
10	Xin et al	January-March 2020	31	106	17.9
11	Cheng et al	January -March 2020	100	151	4.6 (2.3-9.3)
12	Ng et al	January-April 2020	1114	1779	5·9 (4·9-7·1)
13	Park et al	February-March 2020	97	225	15.1 (10.8-20.6)
14	Wang et al	February -March 2020	41	335	23
15	Son et al	February-March 2020	108	196	8.2 (4.7-12.9)

Continued.

S. No.	Author	Enrollment dates	Index cases no.	Household contacts no.	Household SAR% CI 95%
16	Pett et al	February-April 2020	27	44	15.9 (6.6-30.1)
17	Kuba et al	February-May 2020	78	174	12.1 (7.6-17.9)
18	Wilkinson et al	March-April 2020	102	279	14.7 (10.5-18.8)
19	Chaw et al	March-April 2020	19	264	10.6 (7.3-15.1)
20	Ratovoson et al	March-June 2020	96	179	38.8 (19.5-58.2)
21	Semakula et al	March-July 2020	2216	615	2.93 (1.85-4.60)
22	Hu et al	Till March 2020	100	267	17.2 (12.9-22.3)
23	Miller et al	March-November 2020	172	431	33 (25-40)
24	Cerami et al	April-October 2020	100	204	60 (53-67)
25	Gomaa et al	April-October 2020	23	98	89.8 (82.2-94.3)
26	Ogata et al	August 2020 - February 2021	236	496	25.2 (21.6-29.2)

*Not available (--)

Table 2: Characteristic of the study based on location.

S. No.	Article/study	Location	Type of contact tested	Type of study
	China			
1	Wu et al	Zhuhai, China	Symptomatic and asymptomatic	Prospective
2	Bi et al	Shenzhen, China	Symptomatic and asymptomatic	--
3	Li et al	Wuhan, China	Symptomatic and asymptomatic	Retrospective
4	Yi et al	Wuhan, China	Symptomatic and asymptomatic	Retrospective
5	Xin et al	Qingdao, China	Symptomatic and asymptomatic	Prospective
6	Luo et al	Guangzhou, China	Symptomatic and asymptomatic	Prospective
7	Zhang et al	Guangzhou, China	Symptomatic, asymptomatic and presymptomatic	--
8	Wang et al	Beijing, China	Symptomatic and asymptomatic	Retrospective
9	Hu et al	Guangzhou, China	Symptomatic and asymptomatic	--
	South Korea			
10	National emergency response center team (COVID-19)	South Korea	Symptomatic and asymptomatic	--
11	Park et al	Seoul, South Korea	Symptomatic, Presymptomatic and asymptomatic	--
12	Son et al	Busan, Korea	Symptomatic and asymptomatic	--
	Japan			
13	Kuba et al	Okinawa, Japan	Symptomatic	--
14	Ogata et al	Tsuchiura, Japan,	Symptomatic and asymptomatic	Cross-sectional
	USA			
15	Cerami et al	North Carolina, USA	Symptomatic and asymptomatic	Prospective
16	Burke et al	USA	Symptomatic and asymptomatic	--
	Taiwan			
17	Cheng et al	Taiwan	Symptomatic and asymptomatic	Prospective
18	Hsu et al	Taiwan	Symptomatic	--
	Ireland			
19	Pett et al	Northern Ireland	Symptomatic	--
20	Wilkinson et al	Winnipeg health region Canada	Symptomatic	--
	Darussalam			
21	Chaw et al	Brunei Darussalam	Symptomatic and asymptomatic	--

Continued.

S. No.	Article/study	Location	Type of contact tested	Type of study
	Madagascar			
22	Ratovoson et al	Antananarivo, Madagascar	Symptomatic and asymptomatic	Prospective
	Rwanda			
23	Semakula et al	Rwanda	Symptomatic and asymptomatic	--
	England			
24	Miller et al	England	Symptomatic and asymptomatic	Prospective
	Egypt			
25	Gomaa et al	Egypt	Symptomatic and asymptomatic	--
	Singapore			
26	Ng et al	Singapore	Symptomatic	Retrospective

*Not available (--)

Table 3: SAR by household contact age group (A).

S. No.	Study	Household-contacts	Children	Adult	Old
			SAR% 95% CI		
1.	Wu et al	148	4.8[A] (0.6-28.1) 40[B] (13.8-73.5)	25[C] (12.8-43.1)	41.9[D] (23.5-62.9)
2.	Li et al	392	4 [E]	20.5[F]	12.7[D]
3.	Miller et al	431	16[H] (4-28) 33[I] (19-48)	36[J] (28-45)	32[K] (14-51)
4.	Ogata et al	496		23.2[L] (19.3-27.6)	33.3[G] (24.8-43.1)
5.	Kuba et al	174	0[M]	0[O] 33.3[P] (7.5-70.1) 20[Q] (4.3-48.1) 12.5[R] (1.6-38.3)	16.7[S] (2.1-48.4) 40.9[T] (20.7-63.6)
6.	Ratovoson et al	179	25[U] (13.2-41.5)	24.6 [V] (14.5-38) 50[W] (33.6-66.4)	30.2[K] (17.6-46.3)
7.	Wang et al	335	36.1[E]	69.6[F]	

Note: Definition of age group (in years): A=0-3; B=4-18; C=19-60; D>60; E<18; F≥18; G≥60; H=0-10; I=11-18; J=19-54; K≥55; L≤59; M<10; N=10-19; O=20-29; P=30-39; Q=40-49; R=50-59; S=60-69; T>69; U<15; V=15-34; W=35-54.

Table 4: SAR by household contact gender.

S. No	Study	Household-contacts	Male	Female
			SAR% 95% CI	
1	Wu et al	148	30.2 (18.5-45.1)	36.3 (24.6-49.7)
2	Li et al	392	15.6	17.1
3	Miller et al	431	34 (25-43)	31 (22-39)
4	Ogata et al	496	24.1 (19.0-30.1)	26.1 (21.2-31.7)
5	Kuba et al	174	7.1 (2.4-15.9)	15.4 (9.1-23.8)
6	Ratovoson et al	179	27.7 (18.1-38.4)	34.1 (24.6-44.8)

Table 5: SAR by household contact relationship status: spouse or other.

S. No.	Study	Household-contacts	Spouse	Other
			SAR% 95% CI	
1	Wu et al	148	52.2 (32.5-71.2)	37.3 (22.3-55.2)
2	Li et al	392	27.8	17.3
3	Ogata et al	496	37.8 (29.6-46.8)	21.2 (17.4-25.6)
4	Kuba et al	174	22.6 (12.32-36.2)	20.8[A] (7.1-42.2) 4.2[B] (0.9-11.7) 10[C] (0.3-44.5)
5	Chaw et al	264	41·9 (24·1-60·7)	14·1[B] (7·8 23·8)

Continued.

S. No.	Study	Household-contacts	Spouse	Other
6	Burke et al	15	25 (4-38)	--

*Not available (--), *Definition for other contacts A: Parent, B: Child and C: Sibling.

Key finding of household transmission in COVID-19

On the basis of age group

The household SAR was higher among household adults and older age group compared to the children household-contacts. It was observed that children less than 18-20 years had lower SAR.

According to a study by Li et al conducted in Wuhan, China, SAR in children under 18 years of age was 4% while in age group above 18 years SAR was 20.5%.[20] Another study done by Rotovoson et al in the Madagascar stated SAR as 25% in age group under 15 years, 24.6% in 15 to 34 years, 50% in age group 35 to 54 and 30.2% in age group above or equal to 55 years.[17] Wang et al gave SAR of 36.1% for under 18 years and 69.6% for equal or above to 18 years.[16] Similar findings were seen in studies done by Miller et al and Kuba et al (Table 3).

On the basis of gender

The majority of the studies reporting household SAR in males and females found SAR to be slightly higher in females compared to males. A study done by Wu et al in Zhuhai, China, reported SAR in males as 30.2% while in females as 36.3%.[12] Another study by Kuba et al in Japan, observed SAR to be 7.1% in males and 15.4% in females.[19] Similar result was observed in other studies conducted in England, Madagascar and China (Table 4).

On the basis of relationship

Secondary attack rates were found to be greater in spouse compared to other categories of household-contact. SAR of 52.2% was reported in spouse compared to 37.3% in other household-contacts as seen in study done by Wu et al.[12]

Similarly, Li et al reported SAR of 27.8% in spouse and 17.3% in other family members.[20] Studies done by Ogata et al, Kuba et al and Chaw et al also supported the same result (Table 5).

Other key findings

The articles were further studied in-depth to determine COVID-19 transmission features among household-contacts. Based on this, the following observations were made.

SAR in household contact was higher than in overall contacts as mentioned in the research done by Zhang et al in which overall SAR was 3.3% and household SAR was 16.1%.[24] It also stated that household-contacts have 12 times more risk of infection. Another study done by Chaw et al gave an overall attack rate of 2.9% while the household attack rate was 10.6%.[29] Semkuala et al reported SAR of 1.77% and a household attack rate of 5.2%.[30]All these studies suggest that household-contacts play a major role in the spread of the coronavirus disease, 2019.

According to the study of Luo et al in terms of exposure settings, contacts within households had a higher risk of secondary infection (10.3%) than people exposed in health care settings (1.0%) and those exposed during public transportation (0.1%).[22] Semakuala et al, stated that the household-contacts of index cases had approximately two times the risk of getting infected in comparison to the contacts in other community settings such as shops or markets.[30] Another study done by Ng et al found that the secondary clinical attack rate was 5.9% for household-contacts, 1.3% for work contacts, and 1.3% for social contacts. All these studies mark the household as a major exposure setting for COVID-19.[16]

In a study by Hu et al it was found that the highest risk of infection was in household-contacts with a SAR of 17.2%.[31] Wang et al, found that daily frequent contact with the primary case increased the probability of household transmission by 18 times (OR=18.26).[16] The study conducted by Wu et al, also provided similar results. Therefore, increased contact frequency with the index case was linked to a high SAR.

According to Kuba et al, the SAR was low (4.5%) when the period from the onset of symptoms to the isolation of index cases within the household was in three days.[19] In another study done by Li et al the SAR was 0% in household-contacts with index cases who self-quarantined since the onset of the symptoms whereas the SAR was 16.9% in the household-contacts with index cases who were not quarantined.[20] In a study conducted by Cheng et al, it was observed that there was zero transmission in contacts exposed to index cases after five days of symptom onset compared to SAR of 1% in those whose exposure started in five days of symptom onset.[25] SAR risk has been minimized by isolating or quarantining index cases (just after symptoms onset). Though some studies done by Wu et al and Miller et al reported no significance in isolation of the index case. However, the precision of self-isolation guidelines followed was not assessed.[12,32]

According to Park et al the household SAR among symptomatic cases was 16.2% while in asymptomatic cases SAR was 0% (zero household-contacts acquired secondary infection).[26] In a study by Chaw et al, the household SAR of COVID-19 symptomatic cases was greater (14.4%) than compared to presymptomatic or

asymptomatic cases (5.4%).[29] Luo et al also found that the SAR was high for severe or critical cases- 6.2%, compared to mild- 3.3%, moderate- 5.6% and asymptomatic- 0.3%.[22]

In a study conducted by Kuba et al it was observed that a higher Secondary Attack Rate was seen among household members with the underlying disease (36%) compared to those without the underlying disease (11.9%).[21] Wu et al, also stated similar results with SIR/SAR 58.1% in members with underlying disease and SIR/SAR 23% in members having no underline medical condition.[12]

Wu et al reported that the household members not using protective measures after illness onset were more prone to infection with a SIR/SAR of 45.3% compared to those who used protective measures with a SIR/SAR of 15.8%.[12] Similar results were found by Wang et al who stated that face mask use by the index cases and other household-contacts was effective by 79% in reducing the transmission of coronavirus disease.[17]

According to Rotovoson et al if the primary case had respiratory symptoms the SAR was high (35.5%) than the case which had no respiratory symptoms (11.7%).[17] Hu et al, found that the index cases with respiratory symptoms like cough were associated with a higher risk of infection in contacts. The SAR was 2.9% if there was no dry cough compared to 5.8% when the index case had a dry cough.[31] Similarly, according to Miller et al, index cases with respiratory symptoms had a SAR of 37% and those without respiratory symptoms had a SAR of 6%.[32]

DISCUSSION

This systematic study examined SAR statistics from different countries and reviewed the different elements of secondary transmission of COVID-19 in contacts within the households. It was observed that the household-contacts had a higher SAR in comparison to other contacts like health care setting contacts, work contacts, or other community contacts such as shops. The high risk of transmission in the household setting can be explained due to prolonged, more frequent, and closer interactions than contacts occurring at the workplace or in other social settings.[5] Another fact which holds significance is that wearing the mask was mandatory in public settings in the majority of the countries but not in households.[22]

The household SAR was found to be varying across the studies. It could be due to multiple factors, first - the definition of household-contacts was varying, secondly - there were different testing protocols, and third - testing of only symptomatic cases in some studies. Though most of the studies reported SAR under 18%, one study conducted in Egypt by Gomaa et al, reported SAR 89.8% which is much higher than other reported studies.[33] According to the study this is maybe due to behavioural factors.[33] Residents of households might not have quarantined themselves from the index case or not have used the personal protective equipment properly as per the recommendation of the health authorities.[33] Another study conducted by Cerami et al, in the USA reported a very high SAR of 60%.[12] According to the study, the high SAR was due to longer follow-up period as compared to other studies.[12]

The systematic review helped in the identification of susceptible populations in the households. Adults and older individuals are more susceptible to the secondary transmission of SAR -CoV-2 as compared to children. The accurate reason for varying SAR in adults and children needs to be studied further since various factors such as contact behaviour, household members' occupation, etc might impact secondary transmission. Another susceptible population for SAR is spouses. The SARs were considerably higher in spouses than in other family members. This might be attributed to a longer period of virus exposure, as they are actively involved in the patient's caregiving activities which may have resulted in prolonged close contact. Also, spousal contact involves spending a long period of time, and usually, they eat and sleep in the same room with the index case comparatively to other members of the family.[34] The household SAR in the female population was slightly higher compared to males. This can be due to their more active involvement in many household activities leading to more frequent interaction with the index case, however, to accurately determine the association of gender with COVID-19 transmission more research is needed.

This review also recognized the importance of household infection control procedures like self-quarantine and using protective measures like wearing masks. In the majority of the studies, where the index case quarantined/isolated self immediately after symptom onset, it had significantly lowered the Secondary Attack Rate indicating the importance of this intervention. Also using protective measures like face masks lowered the risk of coronavirus disease transmission by 79%.[16] Our study also observed that respiratory symptoms lead to high SAR in household-contacts. This outcome was not surprising, as it is already known that infection spreads through droplets. These droplets are generated when an infected person is coughing or sneezing.[31]

This systematic review had some limitations. The first one is the data gaps due to unprepared health systems in various countries for the pandemic. This may have contributed to bias in the estimation of SAR. Another limitation is the significant variability in SAR found in studies. This is most likely due to the difference between the index case and household contact definitions, method of testing like in some countries nucleic-acid test along with radiographic examination was utilized for diagnosis whereas in some of the countries only RT-PCR was used, sociodemographic variables, household features like density, air ventilation, and country-specific or local regulations regarding COVID-19. One major limitation

was that some studies only tested symptomatic household-contacts which would have missed asymptomatic and subclinical cases and may have caused underestimation of SAR. Also, the different methods used for estimating the total number of household secondary cases in the studies might have contributed to bias in the calculation of SAR. The studies sometimes are not able to rule out infections from outside the household. Non-household-contacts like healthcare settings, workplace, market, etc may also have led to transmission and because of this, household SAR could be overestimated. The results of this systematic review confirm that the household is an important setting for the transmission or spread of SARS-CoV-2. The main strength of this review is that it systematically involves publicly available papers on SAR of SARS-CoV-2, transmission in the household and its related factors, thus helping to have a good level of understanding.

CONCLUSION

This review concluded that household contacts are the most susceptible population for secondary transmission of COVID-19. Households provide an environment for high or often frequent contact between the index case and the members of the household which increases the risk of getting infected. Three main points were derived from the study i.e.; (1) most vulnerable groups for secondary transmission in homes were adults, old age people and spouses; (2) symptomatic cases are more prone to spread the infection as compared to asymptomatic cases; and (3) self-isolation and using protective measures reduce the risk of transmission. Thus, this review helps to understand the transmission dynamics of SARS-CoV-2 in households and the major factors related to it.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Liu T, Liang W, Zhong H, He J, Chen Z, He G, et al. Risk factors associated with COVID-19 infection: a retrospective cohort study based on contacts tracing. Emerging microbes and infections. 2020;9(1):1546-53.
2. India: WHO Coronavirus Disease (COVID-19) Dashboard with Vaccination Data. Available at: https://covid19.who.int. Accessed on 17 October 2021.
3. WHO. Facts about COVID-19, 2021. Available at: https://www.who.int/docs/default. Accessed on 17 October 2021.
4. Wu J, Huang Y, Tu C, Bi C, Chen Z, Luo L, et al. Household Transmission of SARS-CoV-2, Zhuhai, China, 2020. Clin Infect Dis. 2020;71(16):2099-108.
5. Ng OT, Marimuthu K, Koh V, Pang J, Linn KZ, Sun J, et al. SARS-CoV-2 seroprevalence and transmission risk factors among high-risk close contacts: a retrospective cohort study. Lancet Infectious Diseases. 2021;21(3):333-43.
6. Xin H, Jiang F, Xue A, Liang J, Zhang J, Yang F, et al. Risk factors associated with occurrence of COVID-19 among household persons exposed to patients with confirmed COVID-19 in Qingdao Municipal, China. Transbound Emerg Dis. 2021;68(2):782-8.
7. Phucharoen C, Sangkaew N, Stosic K. The characteristics of COVID-19 transmission from case to high-risk contact, a statistical analysis from contact tracing data. E Clinical Med. 2020;27:100543.
8. Health, Erika EdwardsErika Edwards is a, Writer MN, News rfN. Family clusters: A common pattern for how the coronavirus spreads. Available at: https://www.nbcnews.com/health/health-news/family-clusters-common-pattern-how-coronavirus-spreads-n1150646. Accessed on 17 October 2021.
9. Qiu X, Nergiz AI, Maraolo AE, Bogoch II, Low N, Cevik M. The role of asymptomatic and pre-symptomatic infection in SARS-CoV-2 transmission-a living systematic review. Clin Microbiol Infect. 2021;27(4):511-9.
10. Fung H, Martinez L, Alarid-Escudero F, Salomon J, Studdert D, Andrews J, et al. The household secondary attack rate of SARS-CoV-2: A rapid review. Clinical Infectious Diseases. 2020;73.
11. Li F, Li Y, Liu M, Fang L, Dean NE, Wong GWK, et al. Household transmission of SARS-CoV-2 and risk factors for susceptibility and infectivity in Wuhan: a retrospective observational study. Lancet Infectious Diseases. 2021;21(5):617-28.
12. Cerami C, Rapp T, Lin F, Tompkins K, Basham C. High household transmission of SARS-CoV-2 in the United States: living density, viral load, and disproportionate impact on communities of color. MedRxiv. 2021;03:12.
13. Household transmission investigation protocol for coronavirus disease 2019 (COVID-19). Available at: https://apps.who.int/iris/bitstream/handle/10665/331464/WHO-2019-nCoV-HHtransmission-2020.3-eng.pdf
14. Burke RM, Balter S, Barnes E, Barry V, Bartlett K. Enhanced contact investigations for nine early travel-related cases of SARS-CoV-2 in the United States. PLoS One. 2020;15(9):e0238342.
15. Bi Q, Wu Y, Mei S, Ye C, Zou X, Zhang Z, et al. Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. Lancet Infectious Diseases. 2020;20(8):911-9.
16. Wang Y, Tian H, Zhang L, Zhang M, Guo D. Reduction of secondary transmission of SARS-CoV-2 in households by face mask use, disinfection and social distancing: a cohort study in Beijing, China. BMJ Global Health. 2020;5:e002794.

17. Ratovoson R, Razafimahatratra R, Randriamanantsoa L, Raberahona M, Rabarison HJ, Rahaingovahoaka FN, et al. Household transmission of COVID-19 among the earliest cases in Antananarivo, Madagascar. Influenza Other Respir Viruses. 2021;08:10.
18. Wilkinson K, Chen X, Shaw S. Secondary attack rate of COVID-19 in household contacts in the Winnipeg Health Region, Canada. Canadian J Public Health. 2021;112(1):12-6.
19. Kuba Y, Shingaki A, Nidaira M, Kakita T, Maeshiro N, Oyama M, et al. The characteristics of household transmission during COVID-19 outbreak in Okinawa, Japan from February to May 2020. Jpn J Infect Dis. 2021;04:30.
20. Li W, Zhang B, Lu J, Liu S, Chang Z, Peng C, et al. Characteristics of Household Transmission of COVID-19. Clinical Infectious Diseases. 2020;71(8):1943-6.
21. Hsu C, Wang J, Huang K, Fan AC, Yeh Y, Chen SL. Household transmission but without the community-acquired outbreak of COVID-19 in Taiwan. J Formos Med Assoc. 2021;120(1):S38-S45.
22. Luo L, Liu D, Liao X, Wu X, Jing Q, Zheng J, et al. Contact Settings and Risk for Transmission in 3410 Close Contacts of Patients With COVID-19 in Guangzhou, China: A Prospective Cohort Study. Ann Intern Med. 2020;173(11):879-87.
23. Coronavirus Disease-19: Summary of 2,370 Contact Investigations of the First 30 Cases in the Republic of Korea. Osong Public Health Res Perspect. 2020;11(2):81-4.
24. Zhang W, Cheng W, Luo L, Ma Y, Xu C, Qin P, et al. Secondary Transmission of Coronavirus Disease from Presymptomatic Persons, China. Emerg Infect Dis. 2020;26(8):1924-6.
25. Cheng H, Jian S, Liu D, Ng T, Huang W, Lin H. Contact Tracing Assessment of COVID-19 Transmission Dynamics in Taiwan and Risk at Different Exposure Periods Before and After Symptom Onset. JAMA Intern Med. 2020;180(9):1156-63.
26. Park SY, Kim Y, Yi S, Lee S, Na B, CB, et al. Coronavirus Disease Outbreak in Call Center, South Korea. Emerg Infect Dis. 2020;26(8):1666-70.
27. Son H, Lee H, Lee M, Eun Y, Park K, Kim S, et al. Epidemiological characteristics of and containment measures for COVID-19 in Busan, Korea. Epidemiol Health. 2020;42:e2020035.
28. Pett J, McAleavey P, McGurnaghan P, Spiers R, O'Doherty M, Patterson L, et al. Epidemiology of COVID-19 in Northern Ireland, 26 February 2020-26 April 2020. Epidemiol Infect. 2021;149:e36.
29. Chaw L, Koh WC, Jamaludin S, Naing L, Alikhan M, Wong J. SARS-CoV-2 transmission in different settings: Analysis of cases and close contacts from the Tablighi cluster in Brunei Darussalam; 2020.
30. Semakula M, Niragire F, Umutoni A, Sabin N, Ndahindwa V, Rwagasore E, et al. The secondary transmission pattern of COVID-19 based on contact tracing in Rwanda. BMJ Global Health. 2021;6:e004885.
31. Hu P, Ma M, Jing Q, Ma Y, Gan L, Chen Y, et al. Retrospective study identifies infection related risk factors in close contacts during COVID-19 epidemic. Int J Infect Dis. 2021;103:395-401.
32. Miller E, Waight PA, Andrews NJ, McOwat K, Brown KE, Höschler K, et al. Transmission of SARS-CoV-2 in the household setting: A prospective cohort study in children and adults in England. J Infect. 2021;83(4):483-9.
33. Gomaa MR, Rifay ASE, Shehata M, Kandeil A, Kamel MN, Marouf MA, et al. Incidence, household transmission, and neutralizing antibody seroprevalence of Coronavirus Disease 2019 in Egypt: Results of a community-based cohort. PLOS Pathogens. 2021;17(3):e1009413.
34. Ogata T, Irie F, Ogawa E, Ujiie S, Wada K. Secondary Attack Rate among Non-Spousal Household Contacts of Coronavirus Disease 2019 in Tsuchiura, Japan, August 2020-February 2021. Int J Environ Res Public Health. 2021;18(17).
35. Yi B, Fen G, Cao D, Cai Y, Qian L, Li W, et al. Epidemiological and clinical characteristics of 214 families with COVID-19 in Wuhan, China. Int J Infect Dis. 2021;105:113-9.

Cite this article as: Bardhar S, Khanna A. The secondary attack rate (SAR) of SARS-CoV-2 in households: a systematic review. Int J Res Med Sci 2022;10:1737-46.