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Highlights

- The overall SARS-CoV-2 secondary attack rate (SAR) in this study was 17%
- Adults were more likely to be secondary cases than children
- Particular care should be taken if primary cases present with cough and rhinorrhoea
- Kissing or sharing a meal with a SARS-CoV-2 case increased the risk of infection
- Reducing contact in the household immediately is key to prevent onwards transmission
Household transmission of SARS-CoV-2: a prospective observational study in Bosnia and Herzegovina, August – December 2020

Authors: Sanjin Musa 1,2; Esther Kissling 3; Marta Valenciano 3; Faris Dizdar 4; Mia Blažević 1; Anes Jogunčić 2,5; Mirza Palo 4; Lore Merdrignac 3; Richard Pebody 6; Pernille Jorgensen 6

1 Institute for Public Health of the Federation of Bosnia and Herzegovina; Maršala Tita 9, Sarajevo, Bosna and Herzegovina

2 Sarajevo School of Science and Technology, Hrasnička cesta 3a, Sarajevo, Bosnia and Herzegovina

3 Epiconcept, rue Titon 25 Paris, France

4 World Health Organization Office in Bosnia and Herzegovina, Zmaja od Bosne BB, Sarajevo, Bosnia and Herzegovina

5 Public Health Institute of Canton Sarajevo, Dr. Mustafe Pintola 1, Sarajevo, Bosnia and Herzegovina

6 World Health Organization Office Regional Office for Europe, UN City, Marmorvej 51, Copenhagen, Denmark

Corresponding author: Sanjin Musta, MD, PhD
email: s.musa@zzjzfbih.ba
Adress: Maršala Tita 9, Sarajevo, Bosnia and Herzegovina

Other authors email addresses:
Mia Blazevic (m.blazevic@zzjzfbih.ba)
Anes Joguncic (anes.joguncic@outlook.com or anes.joguncic@zzjzks.ba)

Epiconcept:
- Esther Kissling (e.kissling@epiconcept.fr),
- Marta Valenciano (m.valenciano@epiconcept.fr),
- Lore Merdrignac (l.merdrignac@epiconcept.fr)

World Health Organization:
- Faris Dizdar (faris.dizdar@hotmail.com),
- Pernille Jorgensen (jorgensenp@who.int),
- Mirza Palo (palom@who.int),
- Richard Pebody (pebodyr@who.int)
Abstract

**Background**

We estimated the secondary attack rate (SAR) of SARS-CoV-2 and identified risk factors for infection among members of households with a COVID-19 index case to inform preventive measures.

**Methods**

Between 3 August and 19 December 2020, we implemented a household transmission study based on a standardized WHO protocol. We recruited laboratory-confirmed SARS-CoV-2 infected cases through the federal COVID-19 database. Trained contact-tracers interviewed index cases and household members to collect information on demographic, clinical, and behavioral factors. Contacts were followed up for 28 days to identify secondary infections. We estimated SAR and computed odds ratios for risk factors for transmission.

**Results**

We included 383 households and 793 contacts. The overall SAR was 17% (95% CI: 14–21). Contacts had an increased odds of infection if the primary case had a cough and runny nose (OR: 4.31 [95% CI: 1.60–11.63]), and if the contact was aged 18–49 years, kissed the primary case or shared a meal with the primary case, OR: 4.67 (95% CI: 1.83–11.93), OR: 3.16 (95% CI 1.19–8.43) and OR: 3.10 (95% CI 1.17–8.27), respectively.

**Conclusions**

Our results add to the global literature by providing evidence from a middle income setting. Standard preventive measures in households with positive cases remain critical to reduce transmission.
Keywords

Household transmission; SARS-CoV-2; COVID-19; Bosnia and Herzegovina

Introduction

In December 2019, a novel coronavirus SARS-CoV-2 responsible for the disease COVID-19, emerged and subsequently spread globally. The World Health Organization (WHO) declared a public health emergency of international concern on 30th January 2020 (World Health Organization, 2020a). As of September 16 4, 2021, over 224 million laboratory confirmed cases have been reported worldwide (World Health Organization, 2021). In Bosnia and Herzegovina, 224 862 cases have been reported from March 5, 2020, to September 16, 2021 in a population of 3.3 million inhabitants (World Health Organization, Regional Office for Europe 2021).

Households are, and will continue to be, important venues for transmission, even in areas where community transmission is reduced. Transmission within households is higher than in other settings (Thompson et al., 2021). For this reason, tracing household contacts for COVID-19, through identification of persons who may have been exposed to COVID-19 and following them up for 14 days from the last point of exposure, has been a key response measure (World Health Organization, 2020b).

Household transmission surveys conducted as part of the outbreak response provide a strategic approach to rapidly understand key clinical, epidemiological and virological characteristics of an emerging infection, risk factors for transmission, routes of transmission and characterize virus transmission patterns (Bergeri et al, 2021;World Health Organization, 2020c).
Although the knowledge of the virological, epidemiological and clinical characteristics of SARS-CoV-2 has progressed considerably since the beginning of the pandemic, these studies have focused on high income settings. The continued investigation of the transmission of SARS-CoV-2 in other medium and low-income settings, especially as new variants emerge, and understanding of routes of transmission and transmission parameters in a local context remains important to inform and tailor optimal prevention and control measures for COVID-19.

In the Federation of Bosnia and Herzegovina (FBiH), one of the two entities comprising Bosnia and Herzegovina, web-based real-time tracking of suspected COVID-19 cases tested by reverse transcription-polymerase chain reaction (RT-PCR) was launched on 27 March 2020. According to official guidelines, the contact tracing programme aims to identify and test all suspected SARS-CoV-2 cases and those of their contacts who develop symptoms. Contacts who develop symptoms are advised to get tested by RT-PCR in designated COVID-19-units in outpatient healthcare institutions, outpatient clinics, or at drive-through testing locations. Testing may also be done at private laboratories certified by the Federal Ministry of Health. All confirmed and suspected cases are advised to isolate for a minimum 10 days according to guidelines issued by the Institute of Public Health of the FBiH (Institute of Public Health Federation Bosnia and Herzegovina., 2021). Compliance with these measures is overseen by the local health authorities in collaboration with the police, who has the authority to conduct home spot checks and call people who have been instructed to self-isolate. Suspected cases that test negative may end self-isolation as soon as the result is available. Using information on cases recorded in this system, the Institute for Public Health of the FBiH conducted a study with the objective to estimate the secondary attack rate of SARS-CoV-2 among household contacts and identify risk factors for infection in this population to inform optimal preventive measures.
Methods

Survey and study design

We conducted a prospective study among households in which one member had tested positive for SARS-CoV-2 by RT-PCR, between August 3 and December 23, 2020. We selected households in nine districts (out of ten) of the FBiH where district public health institutes had engaged contact tracers supported by WHO. All contact tracers had a background in medical sciences and completed a one-day training course prior to deployment. Contact tracers identified index cases, defined as persons recorded as SARS-CoV-2 positive in the federal real-time web-based database designed to track data on COVID-19 cases. Cases were contacted immediately after laboratory confirmation during the daytime, as required by federal guidelines on contact tracing. Only index cases who reported living with one or more persons when first contacted by the contact tracers were invited to participate in the study together with all their household members. The recruitment of households took place between 3 and 20 August and 15 September 2020 and 27 November 2020. Households were followed up for a total of 28 days after recruitment. The last follow up was on 23 December 2020 (see section on survey data collection below).

A household was defined as two or more persons living in the same apartment or house regardless of kinship. We did not include accommodation facilities such as nursing homes, institutions for the permanent accommodation of persons with special needs, prisons, student and student dormitories, hostels. A household contact was defined as any person living in the same household as the index case at the time of recruitment. Only persons providing informed consent were included. The study was approved by the ethical committee of the Institute for Public Health of FBiH.
Survey data collection

Contact tracers collected data by telephone using questionnaires from the WHO Household transmission investigation protocol for COVID-19 (World Health Organization, 2020c). Index cases and all household contacts were asked about: demographic information (date of birth, gender, occupation, country of residence), household information (household size, number of rooms, number of bedrooms), clinical presentation (including dates of onset), health-care-seeking behaviour (number of visits to health facilities), potential routes of transmission (sharing room, hugging, kissing, sharing a meal, taking care when ill\(^1\) etc.), laboratory confirmation of SARS-CoV-2 (date of test and date of result) along with chronic conditions.

**Figure 1. Case investigation algorithm**

Contacts were followed up for 28 days, with interviews on day 1, 7, 14, and 28. Household contacts also completed a daily symptom diary to record the presence or absence of various signs or symptoms. Verbal consent was requested from each participant.

All questionnaires were administered by telephone by the trained contact tracers. Completed forms were sent electronically to the study coordinators at the Institute of Public Health of FBiH and the WHO Country Office in Bosnia and Herzegovina, where data was entered into the Go.Data software v.2.36.1., a data platform for outbreak investigation and contact tracing (World Health Organization, 2020d).

**Map 1. Total confirmed COVID-19 cases and number of households included in the study by cantons of the Federation of Bosnia and Herzegovina**

\(^1\) It should be noted that the questionnaire did not collect data on the frequency and length of these potential exposures
Definitions of cases and transmission sequence

Index cases and household members were classified into primary, co-primary, secondary, tertiary, non-related cases and non-cases according to the following definitions. A primary case was defined as the household member with RT-PCR confirmed SARS-CoV-2 infection or with COVID-19-like symptoms (reporting at least one of cough, sore throat, coryza, shortness of breath, fever, headache or anosmia/ageusia) with the earliest onset date in the household. When two or more household members had the same earliest symptom onset date for COVID-19-like clinical manifestation, these were defined as co-primary cases, as was any case with COVID-19-like symptom onset the day after a primary case. If date of onset was missing, the swab date of a SARS-CoV-2 RT-PCR confirmed test was taken as a proxy. A secondary case was defined as a household member with COVID-19-like symptoms within 2–14 days of a primary case or with a RT-PCR positive COVID-19 result within 2–14 days of a primary case. Tertiary cases were defined as household members with COVID-19-like clinical manifestation or laboratory confirmation with symptoms presenting more than 14 days after a primary case, but within 14 days of a secondary case. Tertiary cases were described but included as non-cases in the secondary attack rate (SAR) and risk factor analysis.

Household contacts with COVID-19-like symptoms, but no onset date, or contacts with other symptoms than COVID-19-like symptoms (e.g., nausea/diarrhoea) and with no positive SARS-CoV-2 RT-PCR result were classified as possible secondary cases. These household contacts were included as non-cases in the main analysis.

Non-related cases were defined as household members with COVID-19-like clinical manifestation or laboratory confirmation presenting more than 14 days after a primary case, and not within 14 days of a secondary case. We assumed this case was infected outside of the household.
All other household members were defined as non-cases.

Statistical analysis

In the main analysis we excluded households with co-primary cases. We excluded households where there was loss to follow-up in contacts within 14 days of the index case date of onset (or swab if onset date was not available).

The explanatory variables were grouped into a conceptual framework to account for their hierarchical relationship. The levels of the framework consisted of household level variables, contact level susceptibility variables (such as age of contact, sharing room, sharing meals, etc.) and infectiousness factors related to the primary case (age, sex, symptoms, etc.). Individual multivariable models were built for each of these three levels to identify risk factors. A combined model was built in a hierarchical way starting with household level variables, contact level variables and finally primary case variables. All variables with a p-value <0.2 at univariable level were considered for inclusion in the final models. Models were compared using the likelihood ratio test. Variables were retained in the model if the likelihood ratio test p-value was <0.1 in the hierarchical steps. Interactions between contact and primary case variables (age and comorbidities) were explored. Sparse data was taken into account when building models.

Serial interval was defined as time from onset of first symptom in the primary cases to time of onset of first symptom in the secondary case with a cut off of 14 days. The same explanatory variables as in the SAR analysis were considered. Survival regression was then undertaken using the best fitting of the log-normal, Gamma or Weibull distributions.
Sensitivity analyses

In sensitivity analyses we calculated SARs and serial intervals including household with co-
primary cases and in a separate analysis considering those classified as possible secondary
cases as secondary cases. All statistical analysis was performed in Stata (StataCorp. 2019.
*Stata Statistical Software: Release 16*. College Station, TX: StataCorp LLC.). Maps were
created using software ArcGIS version 27.

Results

*Descriptive analysis*

Through contact tracing we identified a total of 1223 index SARS-CoV-2 cases, of which 383
(31%) agreed to participate (Fig. 4). A total of 793 household contacts were identified. We
classified these individuals into 383 primary cases, 21 co-primary cases, and 772 household
contacts. Among the 103 household contacts (13%) presenting with COVID-19-like
symptoms, 58 (56%) were tested by RT-PCR and 43 of them (74%) were positive
(Supplementary Fig. S.1). Among 664 household contacts reporting no COVID-19
symptoms, 143 were tested (22%) and 39 of them (27%) were positive. There were five
households that were lost to follow-up, including five household contacts (Supplementary
Fig. S.1 and supplementary Fig. S.2) and 18 households with at least one co-primary case
(Supplementary Fig. S.2). In the main analysis, we included 360 households, 360 primary
cases, 747 household contacts, among whom there were 119 (16%) secondary cases.

The mean household size was 3.1 persons with 90% of households containing four or fewer
members (Supplementary Table S.1). Among primary cases, 89% (322/360) had at least one
symptom with symptom onset between 17 July and 30 November 2020 (Fig. 1). Among
secondary cases, 75% (89/119) had at least one symptom and symptom onset between the 30
July and 22 November 2020.
Among primary cases, 52% (187/360) reported fever, 40% (145/360) cough, 40% (143/358) anosmia/ageusia, 35% (125/360) headache and 33% sore throat (118/360) (Supplementary figure S.3). Among primary cases, 13% (48/360) did not report any COVID-19-like symptoms. Among secondary cases, 42% (50/119) reported fever, 31% (37/119) cough, 21% (25/119) anosmia/ageusia, 22% (26/119) headache and 23% (27/119) sore throat. Symptoms varied by the age groups 0–17, 18–49 and 50+ years, with fever the most common symptom in all age groups (Supplementary table S.1). Among secondary cases, 27% (32/119) did not report COVID-19-like symptoms.

**Figure 2.** Number of primary cases (n=322)\(^a\) and secondary cases (n=89)\(^b\) by day of onset of symptoms, Federation of Bosnia and Herzegovina, August 2020 to December 2020

Sixty-three percent of the primary cases belonged to the 18–49-year-old age group (228/360). Among household contacts, 58% secondary cases belonged to the 18–49-year-old age group (65/119), compared to 37% non-case household contacts (217/682) (Table 1). Among primary cases, 23% (81/360) had at least one chronic condition. Among household contacts, 16% of secondary cases (19/119) had at least one chronic condition compared to 12% of non-cases (74/682).

**Table 1.** Demographic, medical conditions and outcome of primary COVID-19 cases and their household contacts, Federation of Bosnia and Herzegovina, August 2020 to December 2020

In terms of possible routes of transmission to household contacts, 51% (55/119) secondary cases reported sharing a room with the primary case, compared to 34% (215/628) of non-cases. Among secondary cases, 39% (42/119) hugged the primary case, 34% (36/119) kissed the primary case and 68% (73/119) shared a meal with the primary case, compared to 19%
(120/328), 14% (84/628) and 46% (287/628) of non-case household contacts, respectively (Table 2).

Table 2. Possible routes of transmission of COVID-19 as reported by household contacts, reported by household contacts during illness of the primary case, Federation of Bosnia and Herzegovina, August 2020 to December 2020

Secondary attack rates

We identified secondary cases in 89 households among 360 households: 25% (95% CI: 20–29). The overall SAR was 17% (95% CI: 14–21).

SAR decreased with increasing household size (Table 3). In terms of infectiousness factors, the SAR was higher among households where the primary case had at least one comorbidity, had a cough, or had a cough and a runny nose (OR 2.17 [95% CI: 0.87–5.41], OR: 1.77 [95% CI 0.80–3.91] and OR 2.31 [95% CI: 1.05–5.12], respectively). Among susceptibility related factors, the SAR was higher among households where the contacts were aged 18–49 years old (OR: 6.39 [95% CI: 2.97–17.23]) (Figure 2), shared a room with the primary case (OR: 2.94 [95% CI: 1.42–6.06]), took care of the primary case (OR: 4.76 [95% CI: 1.99–11.35]), hugged the primary case (OR: 3.41 [95% CI: 1.58–7.33]), kissed the primary case (OR: 4.16 [95% CI: 1.37–9.28]), shook hands with a primary case (OR: 3.37 [95% CI: 1.58–7.19]) or shared a meal with the primary case (OR: 3.40 [95% CI: 11.56–7.41]) when the primary case was ill.

Table 3. Univariable estimates of observed secondary attack rates among households, by household level, primary case and household contact characteristics (n=747), Federation of Bosnia and Herzegovina, August 2020 to December 2020

At multivariable level, the SAR was greater if the primary case had a cough and runny nose (OR: 4.31 [95% CI: 1.60–11.63]), and if the contact was aged 18–49 years, kissed the
primary case or shared a meal with the primary case, OR: 4.67 (95% CI: 1.83–11.93), OR: 3.16 (95% CI 1.19–8.43) and OR: 3.10 (95% CI 1.17–8.27), respectively.

**Figure 3. Secondary attack rates by age group of primary cases and household contacts**

*(n=695)*, Federation of Bosnia and Herzegovina, August 2020 to December 2020

**Table 4. Multivariable analysis of risk factors for transmission of COVID-19 in households**

*(n=671)*, Federation of Bosnia and Herzegovina, August 2020 to December 2020

**Serial interval**

We used 84 primary-secondary case pairs for calculating the serial interval. The best fit for the serial interval model used the Weibull distribution (AIC: 162.3) (Supplementary figure S.4). The mean serial interval was 6.4 days (95% CI: 5.7–7.2). No factors related to household, to primary cases (infectiousness factors) or household contacts (susceptibility factors) changed the mean serial interval substantially (Supplementary table S.2).

**Sensitivity analyses**

In sensitivity analyses including possible secondary cases, the SAR was 18% (95% CI: 15–22) and the mean serial interval was 6.7 (5.4–8.1). In sensitivity analyses including co-primary cases, the SAR was 20% (95% CI: 16–23) and the serial interval was 5.6 (4.8–6.3).

**Discussion**

Our study on epidemiological and clinical characteristics of SARS-CoV-2 infections in over 350 households in the FBiH during the first year of the COVID-19 pandemic successfully characterises clinical presentation, secondary attack rates and potential routes of transmission in an Eastern European setting. We found a moderate SAR in a household setting. Adults were more likely to be secondary cases than children. Kissing and sharing a meal with the
primary case were the main risk factors for infection. Cough and runny nose in the primary case were associated with higher risk of infection.

The overall SAR reported in this study was 17%. This is very similar to pooled estimates presented in recent systematic reviews and metanalyses of SARS-CoV-2 household studies (Chian et al., 2020; Madewell et al., 2020; Shah et al., 2020), although significant heterogeneity between studies have been observed. Onward transmission from a primary case, was recorded in a quarter of the households. This is lower than in some studies (Lewis et al., 2020; Rosenberg et al., 2020; Wu et al., 2020) but similar to other published data (Madewell et al., 2020; Tibebu et al., 2021) and in correspondence with evidence of overdispersion in the transmission of SARS-CoV-2, leading to clustering of cases. Differences in the proportion of households reporting any secondary transmission from primary cases in this study compared with other investigations could be explained by differences in household size, availability of isolation/quarantine facilities, prevention measures adopted in the families and households, lack of systematic testing of contacts (testing driven by care-seeking behaviour), characteristics of primary cases (e.g., child versus adult), and household composition (e.g., families versus households with students). Finally, this study took place in the second half of 2020 when knowledge about SARS-CoV-2 and non-pharmaceutical interventions had improved considerably, and access and use of personal protective equipment (e.g., face masks) among the public had increased, which could have contributed to reduced transmission.

Contacts who were adults had a higher risk of infection from a primary case compared with contacts who were children, in keeping with other studies mainly in higher income settings (Madewell et al., 2020). A reduced susceptibility of SARS-CoV-2 infection among children (Galow et al., 2021; Spielberger et al., 2021; Viner et al., 2021) may explain the lower SAR in this contact group. Nonetheless, asymptomatic and paucisymptomatic infections have been
reported to be more common in children than in adults (Viner et al., 2021). Preferential swabbing of persons with symptoms in this study is likely to have underestimated mild and asymptomatic infections especially in children, but also the overall SAR since a relative high proportion of COVID-19 infections are asymptomatic (Yanes-Lane et al., 2020). A higher SAR among younger adults may also reflect a higher closeness between spouses which is supported by the finding that kissing the primary case was independently associated with SARS-CoV-2 infection in the multivariable analysis. Finally, younger adults are likely to be main caregivers of both younger and older household members that are ill, increasing their risk of exposure.

Kissing or sharing a meal with the primary case were the only behavioural factors independently associated with an increased risk of becoming infected at multivariable level. Having meals together with the SARS-CoV-2 positive case has also been reported as a risk factor for infection in a systematic review (Qiu et al., 2020). In another study, sharing a bedroom was linked to increased transmission, while meal sharing was not (Tek Ng et al., 2021). Several factors associated with increased attack rates at the univariable level in this study, including taking care of the case, sharing a room, and hugging did not remain statistically significant in the final model. Since several of these activities are linked with each other, any conclusions derived from multivariable models regarding the role of specific behaviours should be interpreted with caution. Daily activities in families/household ultimately represents different aspects of very close contact over several days and it may not be possible to identify the specific activity(ies) that resulted in infection.

Furthermore, persons who had had contact with a primary case presenting with cough and runny nose (rhinorrhoea) had a higher risk of becoming infected compared with contacts of cases without these symptoms. Although, presymptomatic and asymptomatic individuals can be infectious, they are less so than those presenting with symptoms (Thompson et al., 2021)
Coughing, one of the most common COVID-19 symptoms in addition to fever (Grant et al., 2020), has the potential to disperse more virus particles into the surroundings compared with talking and breathing (Chen et al., 2020). Rhinorrhoea is a less frequently reported symptom of COVID-19 disease (Lovato and de Filippis, 2020). However, SARS-CoV-2 viral shedding from the nose and nasopharynx has been found to be very high (Gengler et al., 2020) also, in the early stages of COVID-19 infection, supporting the findings presented in this paper.

On average, secondary cases presented with symptoms 6.4 days after symptom onset in the primary case. The serial interval falls within the range of estimates from other studies (Alene et al., 2021; Rai et al., 2021). Overall, middle-aged adults more frequently presented with clinical symptoms than children and older adults, except for runny nose (children) and shortness of breath. Children who tested positive for SARS-CoV-2 presented with fewer clinical symptoms than adults similar to observations reported by previous studies (Viner et al., 2020).

Strengths and limitations
This is, to our knowledge, the first published household study from a middle income setting in Europe investigating risk factors for infection, secondary attack rates, and serial intervals for SARS-CoV-2. The analysis was based on a large prospective study, with high completeness, active follow up of contacts, and a detailed questionnaire.

This investigation has a number of limitations. Our analysis may have overestimated SAR since a relatively large proportion of contacts classified as secondary cases were not laboratory confirmed. Also, at the beginning of the study, there were limited public health and social measures in place, including a ceiling on gatherings indoor (maximum of 50 persons) and outdoor (maximum of 100 persons), however, during November additional measures were implemented, including restrictions on movement and work-from-home
policies. It can therefore not be excluded that a proportion of secondary cases were infected outside household, meaning they were misclassified as “household” secondary cases, hence overestimating the SAR. Tertiary cases presenting within 14 days of symptom onset of a primary case may also have been classified erroneously as secondary cases. Conversely, given the presumed high frequency of asymptomatic COVID-19 infections (Yanes-Lane et al., 2020) the low testing rates of household contacts who did not develop symptoms would lead to an under-ascertainment of infections, and thus the SAR, especially among children who more often than adults have asymptomatic infection or present with mild disease. Additionally, we assumed that patients were not secondary cases if their symptoms began less than 2 days and more than 14 days after the onset in the primary case. Without whole genome sequencing, temporal sequences of infection cannot be fully validated.

Furthermore, while the study collected information on a large number of variables, data on the relationship between household members, possible community exposure, use of face masks and other PPE, room ventilation, and previous SARS-CoV-2 infection was not collected. Information on these factors, as well as more detailed data on the exposure variables including the order of magnitude (e.g. number of meals shared, frequency and duration of being in the same room as the index case), would have allowed a more precise assessment of the independent risk factors. Data on age was missing for a relatively high proportion of participants and it was not possible to perform analysis of SAR between different age-groups. Information on those factors would have strengthened the findings, as would serological testing of contacts, which was not performed in this study. Finally, although most cantons were included in this study, including rural and urban areas, households were selected by convenience, hence results may not be fully representative of the population of the FBiH. Moreover, we were not able to assess if the moderate participation rate could have resulted in non-response bias.
Conclusions

Our study suggests that measures to reduce contact between confirmed and suspected SARS-CoV-2 cases and other household members, including self-isolation of cases symptoms, should be implemented immediately to reduce risk of onwards transmission. Particular care should be taken when primary cases present with symptoms such as cough and rhinorrhoea, and all household members should face wear masks when staying in the same room. Persons who are unable to self-isolate safely at home should be accommodated in other locations when possible. Evidence-informed campaigns and interventions to increase awareness and compliance with preventive measures within households, where one or more members test positive for SARS-CoV-2, are needed to reduce transmission in this setting.

Household studies have provided invaluable knowledge on the epidemiology and clinical characteristics of SARS-CoV-2 and continue to be relevant as the pandemic evolves to investigate potential changes in transmission of emerging variants, including routes of transmission and potentially as a tool for investigating vaccine effectiveness and to guide optimal prevention and control measures.

Disclaimer

The authors alone are responsible for the views presented in this manuscript and they do not necessarily reflect the views, decisions or policies of the institutions with which the authors are affiliated.

Acknowledgments

We would like to thank all engaged contact tracers for their efforts and dedication in conducting this study. Thanks also to Jasmin Durmišević who was a member of FBiH team during a preparation of the study. We are very grateful to Nikolaos Panagiotopoulos and Andre Charlett from Public Health England for their kind assistance on designing the analysis.
plan and sharing their experience with implementation of COVID-19 household transmission studies in England.

**Conflict of Interest**

None to disclose

**Funding Source**

This study has been supported by WHO Unity Studies, a global sero-epidemiological standardization initiative, with funding to WHO by the COVID-19 Solidarity Response Fund and the German Federal Ministry of Health (BMG) COVID-19 Research and development (World Health Organization, 2020e).

**Ethical Approval**

The study was approved by the ethical committee of the Institute for Public Health of FBiH.

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Figures and Tables:

Figure 1. Case investigation algorithm
There are 38 primary cases that have no date of onset (lab confirmed only).

There are 30 secondary cases that have no date of onset (lab confirmed only).

Figure 2. Number of primary cases (n=322)\(^a\) and secondary cases (n=89)\(^b\) by day of onset of symptoms, Federation of Bosnia and Herzegovina, August 2020 to December 2020

52 household contacts have missing age.

Figure 3. Secondary attack rates by age group of primary cases and household contacts (n=695)\(^a\), Federation of Bosnia and Herzegovina, August 2020 to December 2020
Figure 4. Total confirmed COVID-19 cases and number of households included in the study by cantons of the Federation of Bosnia and Herzegovina.

Table 1. Demographic, medical conditions and outcome of primary COVID-19 cases and their household contacts, Federation of Bosnia and Herzegovina, August 2020 to December 2020

| Characteristic | Values | Primary cases (N=360) | Household contacts (N=747) | Secondary cases (N=119) | Non-cases *(N=628)* |
|---------------|--------|-----------------------|---------------------------|-------------------------|---------------------|
|               | N (%/IQR) | N (%/IQR) | N (%/IQR) | N (%/IQR)                  |
| Age in years  |        |            |            |                          |
| Median age    | 38 (28-52) | 36 (17-54) | 34.5 (24-50.5) | 37 (16-54)               |
| Missing       | 0      | 52         | 7          | 45                       |
| Age groups    |        |            |            |                          |
| 0-11y         | 4 (1)  | 113 (16)   | 13 (12)    | 100 (17)                 |
| 12-17y        | 10 (3) | 65 (9)     | 4 (4)      | 61 (10)                  |
| 18-49y        | 228 (63) | 282 (41)   | 65 (58)    | 217 (37)                 |
| 50+y          | 118 (33) | 235 (34)   | 30 (27)    | 205 (35)                 |
| Missing       | 0      | 52         | 7          | 45                       |
| Sex           | Male   | 194 (54)   | 358 (48)   | 50 (42)                  |
|               |        |            |            | 308 (49)                 |
Profession: Healthcare worker | Missing | Yes | No | No | No
---|---|---|---|---|---
| Yes | 36 (10) | 19 (3) | 4 (3) | 15 (2) |
| Missing | 3 | 0 | 0 | 0 |

Pregnancy status among women aged 15–49 | Missing | Yes | No | No | No
---|---|---|---|---|---
| Pregnant | 10 (10) | 2 (1) | 0 (0) | 2 (2) |
| Missing | 12 | 0 | 0 | 0 |

### Medical conditions

- **Any chronic condition** (not including pregnancy or "other chronic condition")
  - Yes | 81 (23) | 93 (12) | 19 (16) | 74 (12) |
  - Missing | 1 | 1 | 0 | 1 |

- **Diabetes**
  - Yes | 20 (6) | 22 (3) | 4 (3) | 18 (3) |
  - Missing | 0 | 1 | 0 | 1 |

- **Obesity**
  - Yes | 28 (8) | 25 (3) | 9 (8) | 16 (3) |
  - Missing | 1 | 2 | 0 | 2 |

- **Cancer**
  - Yes | 5 (1) | 7 (1) | 3 (3) | 4 (1) |
  - Missing | 0 | 1 | 0 | 1 |

- **Heart disease**
  - Yes | 20 (6) | 37 (5) | 10 (8) | 27 (4) |
  - Missing | 0 | 1 | 0 | 1 |

- **Asthma**
  - Yes | 8 (2) | 4 (1) | 1 (1) | 3 (0) |
  - Missing | 0 | 1 | 0 | 1 |

- **Chronic lung disease**
  - Yes | 8 (2) | 4 (1) | 0 (0) | 4 (1) |
  - Missing | 0 | 1 | 0 | 1 |

- **Chronic liver disease**
  - Yes | 1 (0) | 0 (0) | 0 (0) | 0 (0) |
  - Missing | 0 | 1 | 0 | 1 |

- **Chronic haematological disease**
  - Yes | 1 (0) | 3 (0) | 0 (0) | 3 (0) |
  - Missing | 0 | 1 | 0 | 1 |

- **Chronic kidney disease**
  - Yes | 2 (1) | 4 (1) | 0 (0) | 4 (1) |
  - Missing | 0 | 1 | 0 | 1 |

- **Chronic neurological disease**
  - Yes | 5 (1) | 3 (0) | 2 (2) | 1 (0) |
  - Missing | 0 | 1 | 0 | 1 |

- **Organ or bone marrow recipient**
  - Yes | 1 (0) | 5 (1) | 0 (0) | 5 (1) |
  - Missing | 0 | 1 | 0 | 1 |

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*Includes 11 cases considered as “later introduction” and thus not secondary cases and 2 tertiary cases.*
Table 2. Possible routes of transmission of COVID-19 as reported by household contacts, reported by household contacts during illness of the primary case, Federation of Bosnia and Herzegovina, August 2020 to December 2020

| Characteristic          | Values | Household contacts (N=747) | Secondary cases (N=119) | Non-cases (N=628)\(^a\) |
|-------------------------|--------|---------------------------|-------------------------|--------------------------|
|                         |        | N (%)                     | N (%)                   | N (%)                    |
| Shared a room           | Yes    | 270 (37)                  | 55 (51)                 | 215 (34)                 |
|                         | Missing| 16                        | 12                      | 4                        |
| Took care of case       | Yes    | 121 (17)                  | 30 (28)                 | 91 (15)                  |
|                         | Missing| 19                        | 12                      | 7                        |
| Hugged case             | Yes    | 162 (22)                  | 42 (39)                 | 120 (19)                 |
|                         | Missing| 22                        | 12                      | 10                       |
| Kissed case             | Yes    | 120 (17)                  | 36 (34)                 | 84 (14)                  |
|                         | Missing| 23                        | 12                      | 11                       |
| Shook hands with case   | Yes    | 152 (21)                  | 40 (37)                 | 112 (18)                 |
|                         | Missing| 23                        | 12                      | 11                       |
| Shared a meal with case | Yes    | 360 (49)                  | 73 (68)                 | 287 (46)                 |
|                         | Missing| 18                        | 12                      | 6                        |
| Used same plate as case | Yes    | 198 (27)                  | 36 (34)                 | 162 (26)                 |
|                         | Missing| 18                        | 12                      | 6                        |
| Slept in same room as   | Yes    | 167 (23)                  | 31 (29)                 | 136 (22)                 |
| case                    | Missing| 15                        | 12                      | 3                        |
| Shared toilet with case | Yes    | 498 (68)                  | 79 (74)                 | 419 (67)                 |
|                         | Missing| 15                        | 12                      | 3                        |
Table 3. Univariable estimates of observed secondary attack rates among households, by household level, primary case and household contact characteristics (n=747), Federation of Bosnia and Herzegovina, August 2020 to December 2020

| Type of characteristic | Characteristic | Value | Secondary cases/All household members* | SAR 95% CI | OR 95% CI |
|------------------------|---------------|-------|----------------------------------------|------------|-----------|
| Unadjusted overall SAR |               |       | 119/1107                               | 17         | 14-21     |
| Household size         |               |       |                                        |            |           |
|                        | 2             | 30/250| 23                                     | 16-30      | Ref       |
|                        | 3             | 39/365| 16                                     | 11-22      | 0.45      | 0.17-1.18 |
|                        | 4             | 33/307| 15                                     | 9-21       | 0.39      | 0.14-1.10 |
|                        | 5+            | 17/185| 12                                     | 4-20       | 0.25      | 0.07-0.96 |
| Household level variables |               |       |                                        |            |           |
| SAR by persons in bedroom | <1 person per bedroom | 16/131| 21                                     | 12-31      | Ref       |
|                        | 1 to <2 persons per bedroom | 77/653| 18                                     | 13-22      | 0.66      | 0.20-2.16 |
|                        | 2 to <3 persons per bedroom | 20/229| 17                                     | 9-24       | 0.58      | 0.15-2.29 |
|                        | 3 + persons per bedroom | 6/94  | 11                                     | 1-21       | 0.27      | 0.04-1.80 |
| Primary case level variables |               |       |                                        |            |           |
| SAR by primary case age | 0-17y         | 6/50  | 20                                     | 4-36       | 1.57      | 0.24-10.17 |
|                        | 18-49y        | 76/742| 17                                     | 12-21      | Ref       |
|                        | 50+y          | 37/315| 19                                     | 12-25      | 1.27      | 0.53-3.01 |
| SAR by primary case gender | Female | 54/518| 17                                     | 12-22      | Ref       |
|                        | Male          | 65/589| 18                                     | 13-23      | 1.17      | 0.53-2.58 |
| SAR by primary case comorbidity status | With no comorbidity | 84/869| 16                                     | 12-20      | Ref       |
|                        | With at least one comorbidity | 35/236| 23                                     | 15-30      | 2.17      | 0.87-5.41 |
| SAR by healthcare worker status of primary case | No health care worker | 110/992| 18                                     | 14-22      | Ref       |
|                        | Health care   | 9/106 | 15                                     | 5-25       | 0.68      | 0.17-      |

2 The number of persons divided by the number of bedrooms – this results in fractions, rather than integers, e.g., 0.75 (if 3 persons and 4 bedrooms).
|                                | workers |   |   | 2.73 |
|--------------------------------|---------|---|---|------|
| **SAR by cough in primary case** |         |   |   |      |
| No cough                       | 59/657  | 15| 11-20 | Ref |
| Cough                          | 60/450  | 20| 15-26 | 1.77|
| **SAR by cough and runny nose in primary case** |         |   |   |      |
| No cough or runny nose         | 43/539  | 14| 9-18  | Ref |
| Cough or runny nose            | 76/568  | 21| 16-25 | 2.31|
| **Any symptoms in primary case** |         |   |   |      |
| No symptoms                    | 4/111   | 7 | 0-14  | Ref |
| Symptoms                       | 115/996 | 18| 15-22 | 6.28|
| **Covid-19-like symptoms in primary case** |         |   |   |      |
| No Covid-19-like symptoms      | 7/134   | 9 | 2-17  | Ref |
| Covid-19-like symptoms         | 112/973 | 18| 15-22 | 3.56|
| **Interaction between primary case and contact level variables** |         |   |   |      |
| **SAR by gender interaction**  |         |   |   |      |
| M to M                         | 16/324  | 14| 7-20  | Ref |
| M to F                         | 48/265  | 20| 15-25 | 2.27|
| F to M                         | 34/228  | 18| 12-23 | 1.76|
| F to F                         | 20/290  | 15| 8-22  | 1.25|
| **SAR by comorbidity interaction** |         |   |   |      |
| Comorb. to comorb.             | 9/109   | 30| 15-45 | Ref |
| Comorb. to none                | 26/127  | 20| 13-28 | 0.37|
| none to comorb.                | 10/65   | 16| 8-25  | 0.23|
| none to none                   | 74/803  | 16| 12-20 | 0.21|
| **Contact level variables, during illness of primary case** |         |   |   |      |
| 0-17y                          | 17/192  | 11| 5-17  | Ref |
| 18-49y                         | 65/510  | 24| 20-28 | 6.39|
| 50+y                           | 30/353  | 16| 10-21 | 2.05|
| **SAR by contact's gender**    |         |   |   |      |
| female                         | 69/555  | 19| 14-23 | Ref |
| male                           | 50/552  | 16| 12-20 | 0.74|
| **SAR by contact's no**        |         |   |   |      |
| 100/931                        | 17     | 13-21 | Ref |
| Contact activity                                      | Yes Count | No Count | Yes Rate | No Rate | Ratio | 95% CI |
|------------------------------------------------------|-----------|----------|----------|---------|-------|--------|
| comorbidity status                                   | yes       | 19/174   | 21       | 13-28   | 1.58  | 0.66-3.76 |
|                                                      | no        | 52/466   | 12       | 8-16    | Ref   |        |
|                                                      | yes       | 55/278   | 20       | 16-25   | 2.94  | 1.42-6.06 |
| Contact shares a room with primary case              | no        | 77/615   | 14       | 10-18   | Ref   |        |
|                                                      | yes       | 30/126   | 26       | 19-32   | 4.76  | 1.99-11.35 |
| Contact took care of primary case                    | no        | 65/571   | 13       | 9-16    | Ref   |        |
|                                                      | yes       | 42/167   | 23       | 17-30   | 3.41  | 1.58-7.33 |
| Contact kissed primary case                          | no        | 71/613   | 13       | 9-16    | Ref   |        |
|                                                      | yes       | 36/124   | 26       | 18-34   | 4.16  | 1.87-9.28 |
| Contact shook hands with the primary case            | no        | 67/581   | 13       | 9-16    | Ref   |        |
|                                                      | yes       | 40/156   | 24       | 17-30   | 3.37  | 1.58-7.19 |
| Contact shared a meal with the primary case          | no        | 34/374   | 10       | 6-15    | Ref   |        |
|                                                      | yes       | 73/368   | 20       | 15-25   | 3.40  | 1.56-7.41 |
| Contact used the same plate as the primary case      | no        | 71/541   | 14       | 10-18   | Ref   |        |
|                                                      | yes       | 36/201   | 20       | 14-27   | 2.12  | 0.86-5.25 |
| Contact slept in the same room as the primary case   | no        | 76/573   | 15       | 11-19   | Ref   |        |
|                                                      | yes       | 31/172   | 18       | 13-24   | 1.56  | 0.72-3.36 |
| Contact shared a toilet with the primary case        | no        | 28/237   | 13       | 7-18    | Ref   |        |
|                                                      | yes       | 79/508   | 17       | 13-21   | 1.85  | 0.81-4.22 |

a Due to the mixed effects logistic regression with household as random effects the SAR is not equivalent to the quotient of secondary cases divided by household members.
Table 4. Multivariable analysis of risk factors for transmission of COVID-19 in households (n=671*), Federation of Bosnia and Herzegovina, August 2020 to December 2020

| Type of characteristic              | Characteristic                     | Value | OR    | OR 95% CI |
|-------------------------------------|------------------------------------|-------|-------|-----------|
| Primary case level variable         | Cough and runny nose               | no    | Ref   |           |
|                                     |                                    | yes   | 4.31  | 1.60-11.63 |
| Contact level variable             | Age group of contact               | 0-17y | Ref   |           |
|                                     |                                    | 18-49y| 4.67  | 1.83-11.93 |
|                                     |                                    | 50+y  | 1.80  | 0.63-5.20  |
| Contact kissing the primary case    | no                                 | Ref   |       |           |
|                                     | yes                                | 3.16  | 1.19-8.43 |
| Contact sharing a meal with the     | no                                 | Ref   |       |           |
| primary case                        | yes                                | 3.10  | 1.17-8.27 |

*Excluded cases with missing data: 52 dropped because of missing age, a further 22 dropped because of missing “kissing”, a further 2 dropped because of missing “sharing meal