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Social contacts in Switzerland during the COVID-19 pandemic: Insights from the CoMix study

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A R T I C L E I N F O

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A B S T R A C T

To mitigate the spread of SARS-CoV-2, the Swiss government enacted restrictions on social contacts from 2020 to 2022. In addition, individuals changed their social contact behavior to limit the risk of COVID-19. In this study, we aimed to investigate the changes in social contact patterns of the Swiss population. As part of the CoMix study, we conducted a survey consisting of 24 survey waves from January 2021 to May 2022. We collected data on social contacts and constructed contact matrices for the age groups 0–4, 5–14, 15–29, 30–64, and 65 years and older. We estimated the change in contact numbers during the COVID-19 pandemic to a synthetic pre-pandemic contact matrix. We also investigated the association of the largest eigenvalue of the social contact and transmission matrices with the stringency of pandemic measures, the effective reproduction number (R_e), and vaccination uptake. During the pandemic period, 7084 responders reported an average number of 4.5 contacts (95% confidence interval, CI: 4.5–4.6) per day overall, which varied by age and survey wave. Children aged 5–14 years had the highest number of contacts with 8.5 (95% CI: 8.1–8.9) contacts on average per day and participants that were 65 years and older reported the fewest (3.4, 95% CI: 3.2–3.5) per day. Compared with the pre-pandemic baseline, we found that the 15–29 and 30–64 year olds had the largest reduction in contacts. We did not find statistically significant associations between the largest eigenvalue of the social contact and transmission matrices and the stringency of measures, R_e, or vaccination uptake. The number of social contacts in Switzerland fell during the COVID-19 pandemic and remained below pre-pandemic levels after contact restrictions were lifted. The collected social contact data will be critical in informing modeling studies on the transmission of respiratory infections in Switzerland and to guide pandemic preparedness efforts.

1. Introduction

The spread of respiratory pathogens, such as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is largely influenced by human contact behavior and mobility (Tomori et al., 2021). SARS-CoV-2, which causes COVID-19, is mainly transmitted via respiratory droplets, aerosols, and close contact, with varying levels of susceptibility and transmissibility across different age groups (Davies et al., 2020; Leung, 2021; Richard et al., 2020). Understanding the number of close contacts between different communities is crucial for estimating and evaluating transmission dynamics (Mossong et al., 2008). This requires empirical data on social contacts that provide information on the mixing behavior of communities over time (Kiti et al., 2023). More specifically, age-stratified matrices of social contacts can provide important information for mathematical models of disease transmission and allow an assessment of the potential impact of physical distancing measures, such as working from home or restrictions for gatherings and events (Jarvis and Van Zandvoort, 2020; Wallinga et al., 2006). Hence, it is critical to collect and analyze age-specific social contact data for individual countries (Mossong et al., 2008), across different settings (Leung, 2021), in the presence of different interventions (Backer et al., 2021; Coletti et al., 2020; Gimma et al., 2022; Hens et al., 2009; Jarvis et al., 2021; Jarvis and Van Zandvoort, 2020; Wong et al., 2023), and over time (Verelst et al., 2021).

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As part of the CoMix study, 19 European countries collected empirical social contact data using a common survey design (Verelst et al., 2021). Within this collaboration, Jarvis and Van Zandvoort (2020) estimated a 74% decline in age-specific social contact data in the UK in early 2020 (Jarvis and Van Zandvoort, 2020). They used the largest eigenvalue approach (Diekmann et al., 1990). The largest eigenvalue of a transmission matrix of the next-generation matrix scales linearly with the reproduction number, the average number of secondary cases from an infected individual (Munday et al., 2021). Thus, the largest eigenvalue approach enables a comparison of the number of contacts between different time points. Consequently, they were able to estimate the change in the reproduction number under different distancing measures using contact information from the CoMix study in the UK and showed that physical distancing measures adopted by the UK population have substantially reduced contact levels, which by affecting the reproduction number can lead to a substantial decline in COVID-19. Coletti et al. (2020) also estimated an 80% reduction in contacts for March and April 2020 in Belgium.

While detailed data on social contact patterns has been collected for many countries (Coletti et al., 2020; Feehan and Mahmud, 2021; Jarvis and Van Zandvoort, 2020; Kiti et al., 2023; Mossong et al., 2008; Verelst et al., 2021; Wong et al., 2023), there has been no nationwide study on contact patterns for Switzerland to date. Smieszek et al. (2009 and 2012) showed in a sample of around 50 participants that heterogeneity in transmission of respiratory pathogens also matters in a Swiss context. But due to the lack of a nationwide study on contact patterns, mathematical modelers have relied on either synthetic contact matrices or on social contact data from neighboring countries, such as Germany (Brugger and Althaus, 2020; Mossong et al., 2008; Prem et al., 2021). The COVID-19 pandemic highlighted that longitudinal monitoring of detailed contact data for Switzerland is necessary for better understanding the impact of interventions on contact behavior and transmission, modeling the spread of respiratory infections across age groups, and guiding decision making during the pandemic response. Therefore, Switzerland participated in the CoMix study.

Here, we present the results of the CoMix study in Switzerland. We collected and analyzed social contact data and estimated the change in contact numbers during January 2021 to May 2022 compared to a synthetic pre-pandemic baseline. Moreover, we investigated the association of the largest eigenvalue of the social contact and transmission matrices with the stringency of pandemic measures, the effective reproduction number R_e, and vaccination uptake. Finally, we discuss the implications of our findings for the future study of social contacts in Switzerland.

2. Methods

2.1. Data

CoMix is a social contact survey that followed participants in 19 European countries throughout the COVID-19 pandemic (Verelst et al., 2021). The design of the CoMix survey is largely based on the POLYMOD study from Mossong et al. (2008). For CoMix, the market research company, Ipsos, enrolled participants for online panels through multi-source recruitment methods, including referral by online suppliers, website banners and advertisements, and search engine marketing. Volunteers who were part of an online panel were sent an email invitation to join the CoMix survey. In Switzerland, we conducted 24 survey waves from 22 January 2021–19 May 2022. The waves were conducted in 6 consecutive panels where participants were followed longitudinally. The aim was to include 1000 participants per panel. Due to loss to follow-up of participants, new participants were also included after the first wave of each panel. The panels were selected to be nationally representative for quotas on age, gender, and region of residence. Participants could answer the questionnaire in three national languages, i.e., German, French, or Italian. The survey included adults aged 18 years and older (in panels A, B, and F) and parents (at least 18 years old) who completed the surveys on behalf of their children (younger than 18 years old; panels C, D, and E). For parents, quotas were set on region only. Participants reported their social contacts made on the day prior to survey participation. A contact was defined as anyone who met the participant in person with whom at least a few words were exchanged, or physical contact was made. The survey data include the gender and exact age of participants or the median age if the exact age was unknown (8.2%). All adult participants reported their ages, but parents only provided an age range for their children, namely <1, 1–4, 5–11, 12–15, and 16–17 years. The data also include information on residence (26 Swiss cantons), place of contact (at home, at work, at school, in a means of transport, or during leisure activity), age range of contacts, contact frequency, contact duration, whether contacts were within the household, whether contacts were individual or in a group, and the date of the contact. The social contact data used for this study are openly available on Zenodo (doi.org/10.5281/zenodo.10147647) and can be analyzed using the R package *socialmixr* (Funk et al., 2022).

For our study, we used CoMix data on social contacts and supplemented the analysis with additional data. We have reported the number of hospitalized patients from Swiss Federal Office of Public Health (FOPH) data to describe the Swiss SARS-CoV-2 epidemic over time. We estimated the effective reproduction number R_e from the number of laboratory-confirmed SARS-CoV-2 cases provided by the FOPH (https://www.covid19.admin.ch/api/data/context) (FOPH, 2023). We estimated the proportion of SARS-CoV-2 variants during the study period from genomic data and combined the proportions with estimates of the growth advantage of the variants from the literature (https://cov-spectrum.org/) (Campbell et al., 2021; Chen et al., 2022; Suzuki et al., 2022). We used the KOF ('Konjunktur-Forschungsstelle', meaning economic research center in English) Stringency Index from Pleninger et al. (2022) (https://datenservice.kof.ethz.ch) as a proxy measure for the stringency of control interventions. We extracted seroprevalence estimates for SARS-CoV-2 of the Swiss population from the Corona Immunitas studies (www.corona-immunitas.ch), which measured seroprevalence from either naturally acquired or vaccine-elicited immunity (Amati et al., 2022; Frei et al., 2023; Tancredi et al., 2023). We extracted data of the synthetic contact matrix for Switzerland from Prem et al. (2021 and 2022) as a pre-pandemic baseline . The synthetic matrix includes the number of contacts for one day. The contacts are divided into 16 age groups (starting at 0 and continuing in 5-year steps). The synthetic contact matrices are based on country-specific demographic and contact data collected as part of the POLYMOD study, which was conducted in eight non-Swiss European countries. We used demographic information of the Swiss population from the Federal Statistics Office (FSO) (www.bfs.admin.ch) (BFS, 2022).

2.2. Analysis

For the analysis of social contact data, we considered five groups of 0–4, 5–14, 15–29, 30–64, and 65+ year olds, which correspond to the age groups used for reporting by Sentinella, the Swiss Sentinel Surveillance Network (Somaini et al., 1986). For simplicity, we assigned the survey participants in the age group of 12–15 year olds to the age group of 5–14 year olds in Sentinella. We converted the age groups of the synthetic contact matrix for Switzerland from Prem et al. (2021). To estimate the number of contacts per survey wave, we split the age group of 15–29 years into two groups of 15–17 and 18–29 years. We randomly truncated the number of reported contacts at 50 contacts to reduce bias from outliers. If participants did not report the exact age of the contact, we sampled their age based on the reported range.

We estimated the crude mean number of contacts per day. Then, we constructed social contact matrices using the R package *socialmixr* (Funk et al., 2022). To account for the weekend effect, we weighted the contacts according to the day of the week, i.e., weekends and weekdays were weighted differently. The weighting compensates for the uneven

Table 1
Description of study population of the CoMix survey. CI, confidence interval.

Survey wave	Time period	Number of participants	Mean number of contacts (95% CI)	Number of newly enrolled participants	Number of missing participants who had been previously enrolled	Number of returning participants after missing at least one wave
A1	22 January 2021–01 February 2021	1555	4.5 (4.3–4.7)	1555	0	0
A2	18 February 2021–26 February 2021	842	4.5 (4.1–4.8)	562	1275	0
A3	04 March 2021–11 March 2021	662	4.1 (3.8–4.3)	327	737	230
A4	18 March 2021–22 March 2021	707	3.6 (3.3–3.9)	32	296	309
A5	15 April 2021–19 April 2021	649	3.6 (3.3–3.9)	31	311	222
A6	29 April 2021–03 May 2021	544	3.6 (3.3–3.9)	27	272	140
A7	13 May 2021–17 May 2021	465	3.4 (3.2–3.7)	17	206	110
B1	03 June 2021–14 June 2021	996	5.0 (4.7–5.3)	996	0	0
B2	02 July 2021–19 July 2021	1559	4.9 (4.7–5.2)	800	237	0
B3	20 July 2021–29 July 2021	1324	4.7 (4.4–4.9)	88	392	69
B4	10 August 2021–16 August 2021	1120	4.3 (4–4.6)	0	393	189
B5	26 August 2021–01 September 2021	953	3.7 (3.5–4)	0	354	187
B6	09 September 2021–15 September 2021	806	4.0 (3.7–4.4)	0	367	220
C1	05 February 2021–09 February 2021	303	8.4 (7.7–9.1)	303	0	0
C2	01 April 2021–08 April 2021	296	8.4 (7.8–9)	150	157	0
D1	08 July 2021–15 July 2021	300	8.0 (7.4–8.5)	300	0	0
E1	12 January 2022–17 January 2022	307	7.0 (6.6–7.4)	307	0	0
E2	14 April 2022–21 April 2022	308	8.1 (7.5–8.8)	140	139	0
F1	09 December 2021–19 December 2021	1001	4.5 (4.2–4.8)	1001	0	0
F2	14 January 2022–20 January 2022	899	3.8 (3.5–4)	158	260	0
F3	10 February 2022–16 February 2022	813	3.7 (3.5–4)	14	209	109
F4	15 March 2022–22 March 2022	727	4.0 (3.6–4.3)	51	137	0
F5	13 April 2022–24 April 2022	700	4.1 (3.8–4.4)	236	297	34
F6	11 May 2022–19 May 2022	592	4.0 (3.7–4.4)	151	300	41

distribution of five working days and two weekend days. Noting, the number of contacts during working days may differ from the number of contacts during leisure time. Weights for the days were calculated as follows:

$$w_{dayofweek} = 5/7/(N_{weekday}/N) \text{ or } 2/7/(N_{weekend}/N)$$

where N is the overall sample size and $N_{weekday}$ and $N_{weekend}$ the number of participants that were surveyed during weekdays and weekends, respectively. We adjusted the daily mean number of contacts (of the survey data and the synthetic contact matrices) using the age distribution of the Swiss population for the year 2021. Data for 2022 was not available while conducting the analysis. We further accounted for reciprocity of contacts. Reciprocity may be lost due to sampling differences in age groups. Contacts should be based on reciprocity, i.e., $m_{ij}N_i$ should be equal to $m_{ji}N_j$:

$$m'_{ij} = (m_{ij}N_i + m_{ji}N_j)/(2N_i)$$

where m_{ij} is the mean number of contacts of age group i with age group j, and $N_{i \text{ or } j}$ is the total number of people in age group i or j. Finally, we generated 100 bootstrap samples of the contact data and followed the same procedure to calculate matrices to account for uncertainty in the reported number of contacts in the survey sample.

From the matrices, we summed the overall number of contacts for survey contacts for the following panels, A and C (22 January to 17 May 2021), B and D (3 June to 15 September 2021), and E and F (9 December 2021–19 May 2022). We compared this number to a synthetic pre-pandemic baseline and calculated the relative number of contacts by age group.

Next, we adapted the next generation approach and calculated the effective contact rate c_{eff} from the largest eigenvalue of the contact matrix C_t from survey wave t (Diekmann et al., 1990):

$$c_{eff} = \mathrm{Eig}(C_t)$$

In the main analysis, we calculated the largest eigenvalue of the contact matrix for each survey wave of the adults pooled with all survey waves of the children. We investigated the association of the largest eigenvalue of the contact matrix with the median of the stringency of pandemic measures and the vaccine coverage using linear regression.

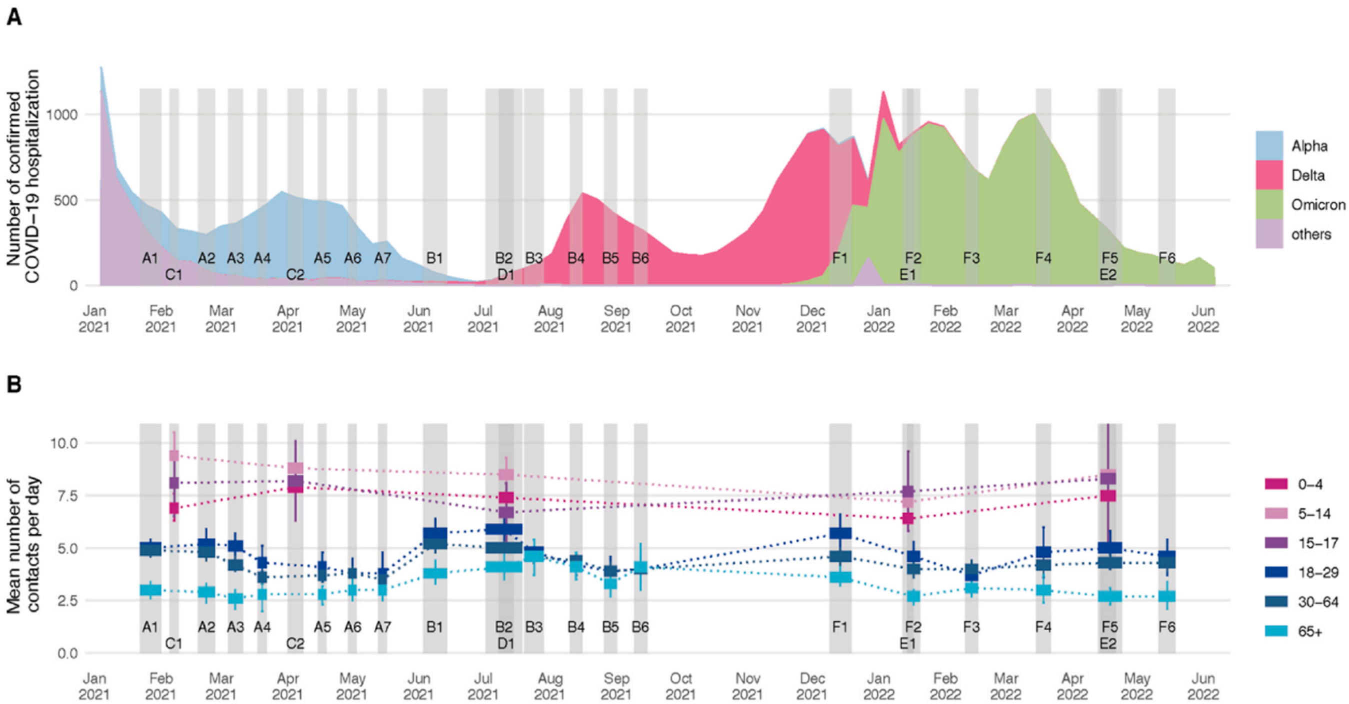

Fig. 1. COVID-19 epidemic and social contact survey in Switzerland. A: Reported number of hospitalized COVID-19 cases reported by the FOPH colored by the proportion of variants sequenced. Gray bars and digits represent each CoMix survey wave. B: Mean number and 95% confidence interval of social contacts by age group and wave.

We also calculated the largest eigenvalue of the transmission matrix that accounts for susceptibility, the level of immune protection, and the relative growth rate of different SARS-CoV-2 variants in proportion to their monitored occurrence (Supplementary Table 1). Precisely, we calculated the largest eigenvalue of the transmission matrix β by multiplying the contact matrices with the outer product ($\otimes$) of the infectiousness and susceptibility vectors for the different age groups and scaled with the relative growth rate κ:

$$\beta = \kappa \ \mathrm{Eig}(C_t \circ (i \otimes s))$$

For simplicity, we set the infectivity i to 1 for all age groups and the baseline susceptibility s to 0.5 and 1 for children and adults, respectively. The lower susceptibility was based on a scenario by Munday et al. (2021) that was informed by a study from the United Kingdom Office of National Statistics. When we considered seroprevalence data, we multiplied the susceptibility vector by one minus the mean of the seroprevalence of corresponding survey period and the level of immune protection. We assumed the level of immune protection to be 90% in our main analysis (Supplementary Table 1). We did not assume any impact of immunity on infectivity. We investigated the association of the largest eigenvalue of the transmission matrix with the median of R_e using linear regression. We estimated R_e from the daily number of laboratory-confirmed SARS-CoV-2 cases using the R package EpiNow2 (Abbott et al., 2020; Abbott et al., 2023). For computational and content reasons, we run intervals of 1.5 months covering the time of survey waves and intervals overlapped for 2 weeks with the previous run. We used an incubation time of 5.2 days with a standard deviation (sd) of 2.8 days (Zhang et al., 2020), a generation time of 5.2 days (sd = 1.72 days) (Ganyani et al., 2020), and assumed a reporting delay of 2 days (sd = 2 days). *Epinow2* takes the weekly noise into account by explicitly considering a weekend effect in reported case numbers.

In a sensitivity analysis, we also considered contact and transmission matrices that included survey waves in adults (participants ≥18 years) with the wave in children (participants younger <18 years) closest in time, and varied our assumptions for susceptibility and the level of immune protection (Supplementary Table 1). All R code is publicly available on GitHub (https://github.com/ISPMBern/comix).

3. Results

Over 24 survey waves from 22 January 2021–19 May 2022, we recorded 18,428 observations from 7084 participants who reported 83,515 contacts (Table 1). Study participants completed a median of 2 (range: 1–7) survey waves. The responses were not always recorded in consecutive survey waves. In the study, 3609 (50.9%) participants were females, 3452 (48.7%) were males, and 23 (0.4%) did not specify. The gender ratio was more balanced in adults (49.7% females and 49.9% males) than children (58.2% females and 41.8% males). The median age of participants was 41 (interquartile range: 26–58) years. Children constituted 14.7% of the sample while older adults (65+ year olds) represented 16.7%. Participants came from all 26 Swiss cantons. The highest proportion came from Zurich (1253, 17.7%) and the fewest came from Appenzell Innerrhoden (9, 0.1%), which is proportional to the cantonal population sizes. The survey panels A and C were dominated by the SARS-CoV-2 Alpha variant, panels B and D by the Delta variant, and panels E and F by the Omicron variant (Fig. 1A). During the study period, the predicted seroprevalence levels for Switzerland overall increased from 17.3% to almost 99.0% due to infection- and vaccine-induced immunity (Supplementary Figure 1).

The number of contacts overall was on average 4.5 (95% confidence interval, CI: 4.5–4.6, interquartile range (IQR): 2–6) per day. Over the entire study period, no statistically significant difference was found between the average number of contacts at the weekend and on weekdays (p-value = 0.6). The number of contacts varied by survey wave (Table 1) and age group (Fig. 1B). Children aged 5–14 years had the highest overall number of contacts with 8.5 (95% CI: 8.1–8.9, IQR: 6–10) per day, whereas 65 years and older reported the fewest (3.4, IQR: 2–4) per day. The numbers of contacts were similar between women (4.2 per day, 95% CI: 4.1–4.3, IQR: 2–6) and men (4.3 per day, 95% CI: 4.2–4.4, IQR: 2–6) (Supplementary Figure 2). The number of contacts also depended on the location where the contact took place, i.e., at

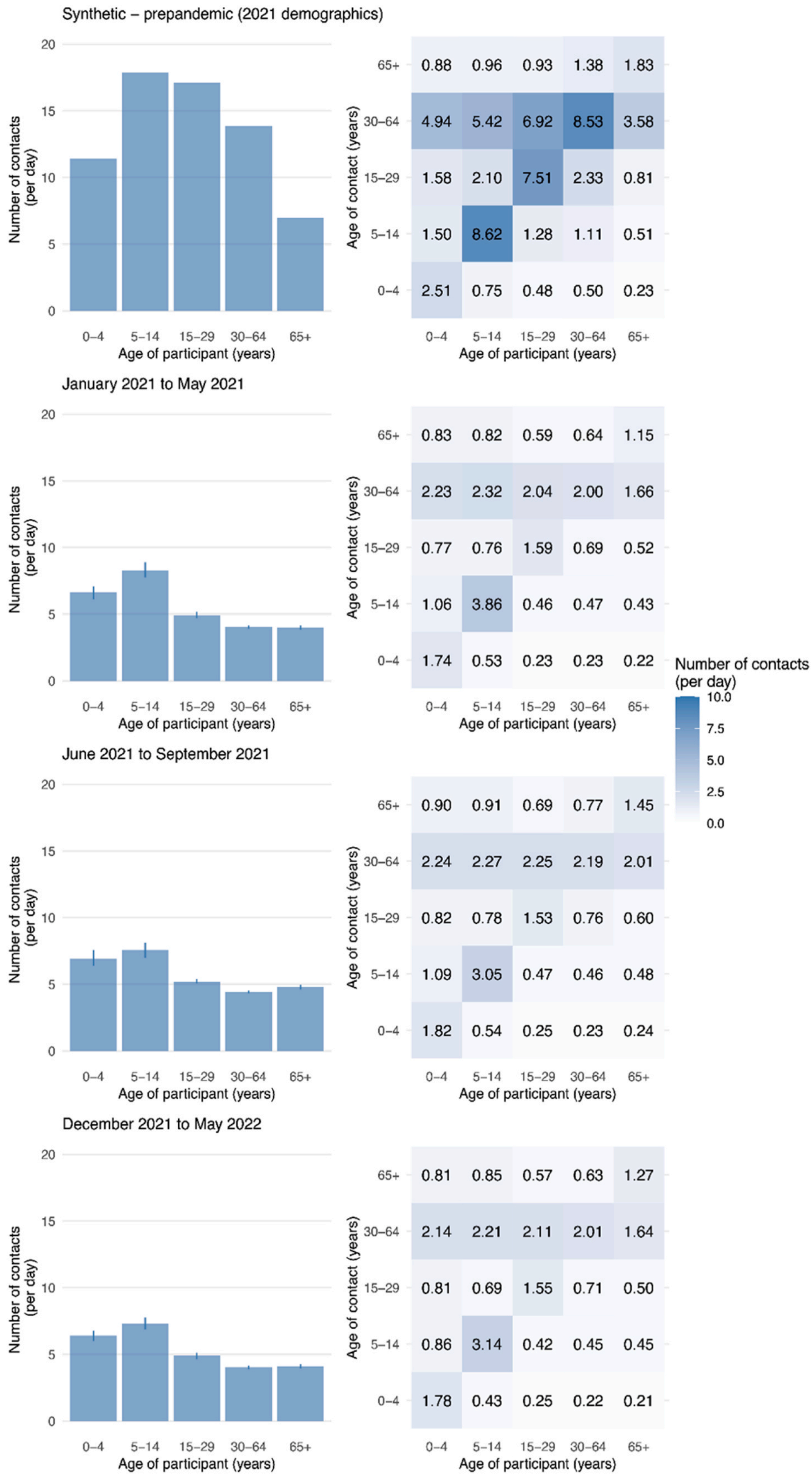

Fig. 2. Number of social contacts per day (left) and social contact matrices (right) for Switzerland**.** The number of contacts was normalized to the Swiss population in 2021. The top row corresponds to the synthetic data representing a pre-pandemic baseline and the other rows correspond to the CoMix data over different survey periods.

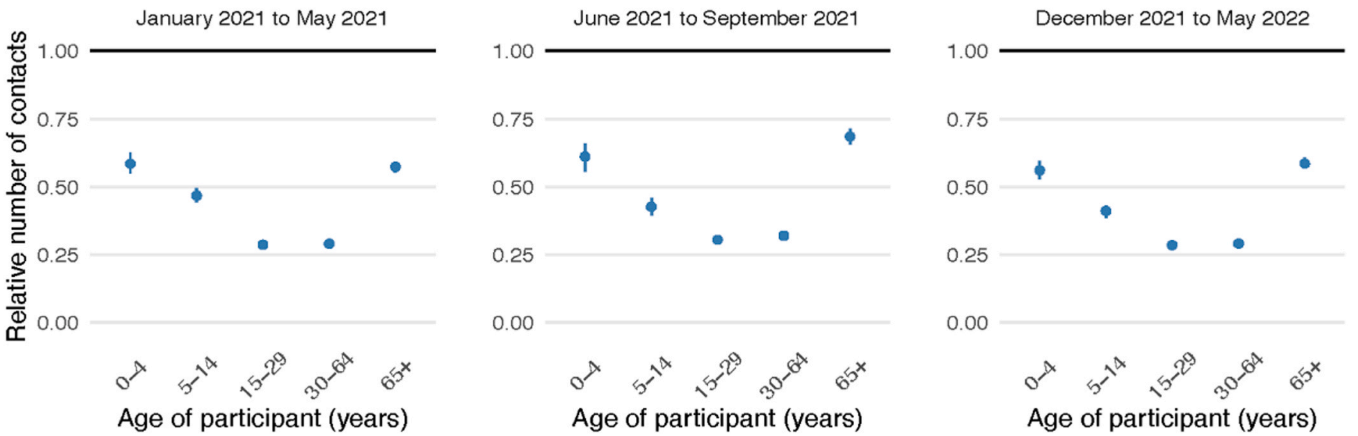

Fig. 3. Relative number of social contacts by age group during the COVID-19 pandemic in Switzerland. The number of contacts from the CoMix study at different survey periods is shown relative to a pre-pandemic baseline. Bars correspond to the 95% confidence interval of 100 bootstrap samples.

home, at work, at school or at another location, as well as the number of waves in which participation took place (Supplementary Figure 2). Overall, 57% of contacts occurred at home (Supplementary Figure 3). Contact frequency between adults and children mainly differed at work (9% and 1%), and school (1% and 9%), respectively.

Comparing the number of contacts to a pre-pandemic baseline, contacts were substantially reduced during the COVID-19 pandemic in Switzerland (Fig. 2). The reductions were similar over all three survey panels (Fig. 3). The range of reduction was 34–47% in 0–4 year old children, 51–61% in 5–14 year old children, 68–73% in 15–29 year olds, 67–72% in 30–64 year old adults, and 29–45% in those aged 65 years or older.

We investigated whether the properties of the social contact matrix were associated with the stringency of pandemic measures and vaccination uptake. The largest eigenvalue of the contact matrix only decreased moderately (-0.1, 95% CI: −0.5–0.3) and increased moderately (0.1, 95% CI: −0.3–0.5) with higher stringency of measures and vaccination uptake, respectively (Fig. 4). We further tested whether the properties of the transmission matrix were associated with R_e during the COVID-19 pandemic in Switzerland. The degree of association strongly depended on the underlying assumptions (Supplementary Figure 4). For the main analysis, we found a positive but non-significant association between the largest eigenvalue of the transmission matrix and R_e with a coefficient of 0.5 (95% CI: −0.4–1.4) (Fig. 5; Supplementary Figure 5).

4. Discussion

In our study, we analyzed social contacts reported by a total of 7084 participants across five age groups and over 24 survey periods from 22 January 2021–19 May 2022. The average number of contacts overall was 4.5 (95% CI: 4.5–4.6) per day and varied by age group and survey wave. The number of reported contacts during the pandemic was substantially lower than before the pandemic. We did not find strong associations between the largest eigenvalue of the social contact and transmission matrices and the stringency of measures, vaccination uptake, or R_e.

This is the first study that includes detailed social contact data by age in a large study population that is representative of the Swiss population in regard to age, gender, and geographical region of residence. The study includes multiple survey waves during critical phases of the COVID-19 pandemic when restrictions were lifted and the vaccination program was rolled out. Furthermore, the data were collected during the circulation of different SARS-CoV-2 variants, namely Alpha, Delta, and Omicron. Lastly, the publicly available social contact data represent an important resource for the future study of the transmission of respiratory infections in Switzerland.

Nevertheless, our study has several limitations. First, as previously mentioned this is the first empirical Swiss study from which social contact matrices for Switzerland could be directly constructed. Consequently, there were no pre-pandemic surveys and we had to rely on the synthetic contact matrix by Prem et al. (2021) to generate a pre-pandemic baseline. The synthetic contact data is based on country-specific demographic and contact data collected as part of the POLYMOD study (Mossong et al., 2008). However, Switzerland was not part of the POLYMOD survey. In addition, participants used a prospective diary and did not record contacts retrospectively, which differs from the CoMix study. The type of data collection can influence the number of contacts (Mikolajczyk and Kretzschmar, 2008). Thus, collecting data and comparisons between different studies have limitations. For example, synthetic matrices could extrapolate artifacts and thus overestimate the number of contacts, or the CoMix method could systematically underestimate them. Second, social contact surveys are prone to biases. Not all participants that were recruited in a panel participated in the same number of waves. We previously showed in the context of vaccination uptake between June and September 2021 that the number of dropouts increased in later survey waves (Reichmuth et al., 2023). Survey fatigue can result from various reasons. For example, participants with more contacts need to invest more time in filling out the survey and thus might be more likely to stop. Loedy et al. (2023) analyzed the impact of drop-outs on the number of contacts and found that drop-outs did not depend on the number of contacts in Belgium. We have therefore not adjusted the number of contacts for dropouts. Third, we conducted fewer waves for children and had a smaller number of participants compared to adults. To overcome this limitation, we pooled all survey waves in children to increase the number of participants. Fourth, we did not investigate differences in viral characteristics for different circulating variants and susceptibility and infectivity between the age groups. We used viral characteristics, such as incubation and generation time of the wild-type of SARS-CoV-2 to estimate R_e and not for different circulating variants. We also only assumed that children are half as susceptible as adults (Davies et al., 2020). Fifth, there is considerable heterogeneity in the number of secondary SARS-CoV-2 cases. The observed numbers of contacts are right-skewed with some participants reporting substantially higher numbers of contacts than the average, which could result in superspreading events (Wegehaupt et al., 2023; Riou and Althaus, 2020). We did not include superspreading when calculating transmission contact matrices, which could influence the comparison with R_e. In addition, SARS-CoV-2 can be transmitted through aerosols. Aerosol transmission can affect secondary transmissions, i.e., R_e, without increasing social contacts that consider only close contacts (Leung, 2021). Sixth, we might miss the impact of regional differences in control measures, vaccination uptake, and

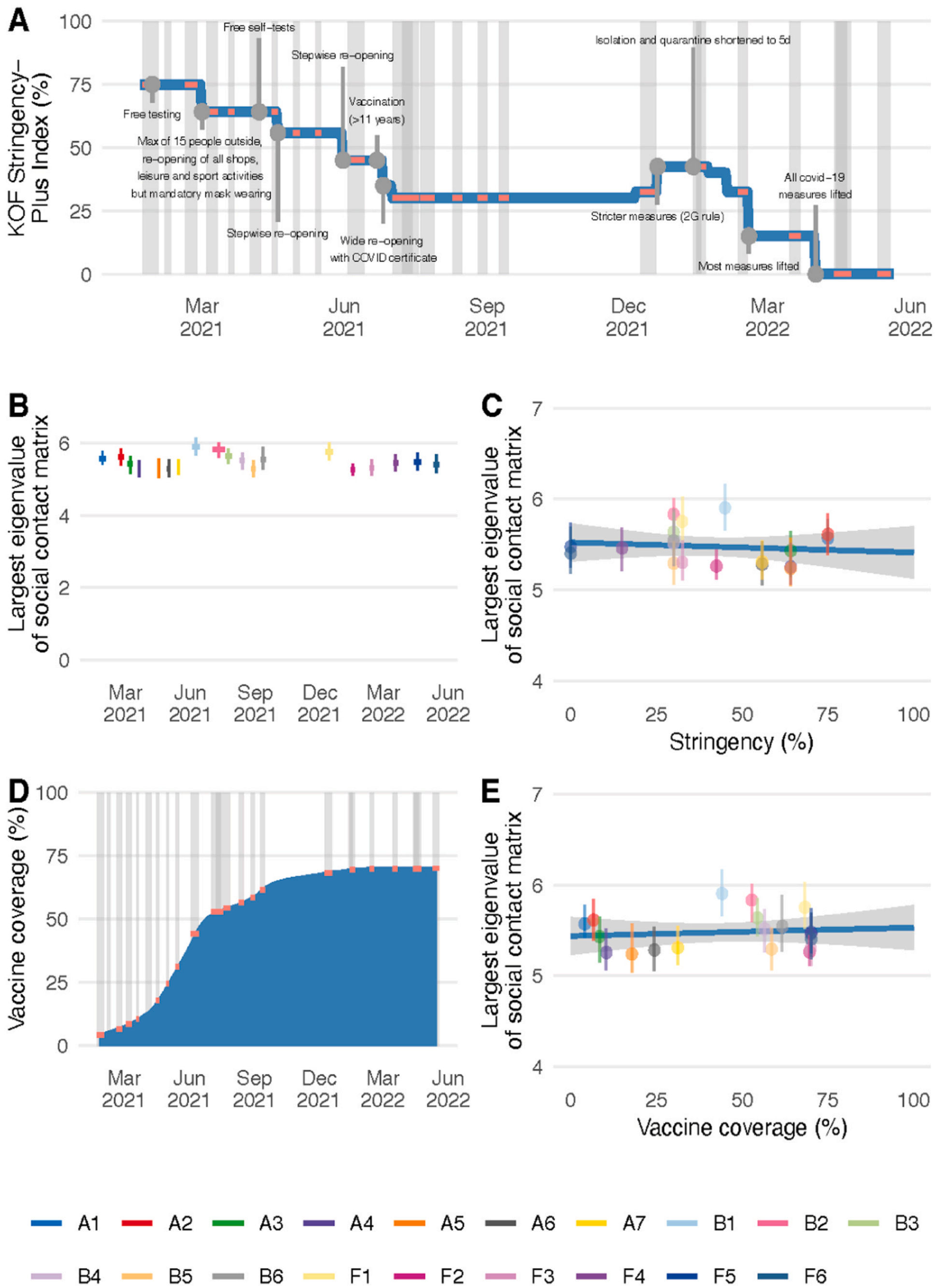

Fig. 4. Largest eigenvalue of social contact matrix. A: The KOF Stringency Index and major events during the COVID-19 pandemic in Switzerland. The values range from 0 (no measures) to 100 (full lockdown) and were adapted from Hale et al. (2021). The gray areas indicate the CoMix survey wave periods and the red bars the median of the KOF Stringency Index for the corresponding survey waves. B: Largest eigenvalue of the social contact matrix by adult survey wave. C: Linear association of stringency of measures with largest eigenvalue of social contact matrix for corresponding survey period. D: Vaccine coverage with the first dose in Switzerland. Red bars indicate the median vaccine coverage for corresponding survey waves. E: Linear association of vaccine coverage with largest eigenvalue of social contact matrix for corresponding survey period. Shaded areas of the linear association correspond to the 95% confidence interval. The survey included adults aged 18 years and older (in panels A, B, and F) (see Table 1 for more details).

adherence because there were too few participants to stratify by region. Finally, constructing a transmission matrix whose largest eigenvalue is expected to correlate with R_e at different time periods of the COVID-19 pandemic in Switzerland proved to be challenging. In contrast, the studies by Davies et al. (2021) and Munday et al. (2021) found that CoMix-based estimates of R_e are in line with laboratory-confirmed cases during the time period from April to November 2020 and before the arrival of the Alpha variant (Davies et al., 2021; Munday et al., 2023). In our survey, the changes in contact rates may have been influenced by considerable noise and survey fatigue and thus cannot fully explain the observed changes in transmission. Instead, it seems that other factors, such as the varying and heterogeneous levels of immunity in the population (Davies et al., 2021; Perez-Guzman et al., 2023; Tan et al., 2023; Viana et al., 2022; Viner et al., 2021; Althaus et al., 2021), that were caused by the Alpha, Delta, and Omicron variants in combination with vaccination and booster campaigns, primarily drove the changes in transmission and decoupled R_e from social contacts. However, these factors are difficult to measure and we restricted our analysis to a few

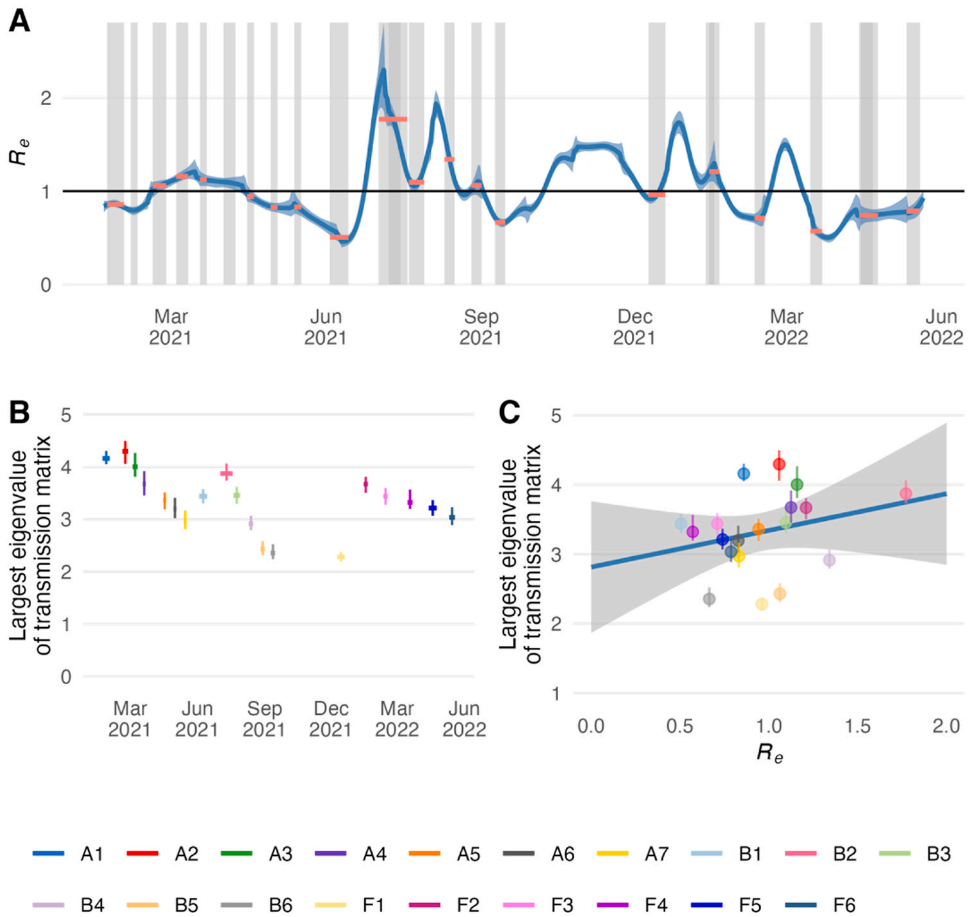

Fig. 5. Largest eigenvalue of transmission matrix. A: Median (blue line) effective reproduction number R_e and 90% confidence interval (blue shades) per day. The median R_e (red lines) for the corresponding survey wave (gray area). B: Largest eigenvalue of transmission matrix per survey period. C: Linear association of the largest eigenvalue of transmission matrix with the median R_e for corresponding survey period. The survey included adults aged 18 years and older (in panels A, B, and F) (see Table 1 for more details).

baseline assumptions about the increased transmissibility of variants and the levels of protective immunity.

The CoMix study in Switzerland is part of a larger Europe-wide project, which enables a comparison of the results between countries (Wong et al., 2023; Jarvis et al., 2023). Wong et al. (2023) compared contact data among 21 European countries including data from Switzerland from 22 January to 17 May 2021 . They showed a sustained reduction in the number of contacts in all countries after the onset of the COVID-19 pandemic. We added with our study that the reduction of contacts in Switzerland persisted until 19 May 2022. Similarly, Jarvis et al. (2023) compared the post-pandemic contact behavior using CoMix data in the UK, Belgium, the Netherlands, and Switzerland and found that numbers of contacts continued to fall in the period from 17 November to 7 December 2022 compared with a pre-pandemic baseline. In 2021, the mean number of contacts among adults in Switzerland varied from 3.4 to 5.0 over all survey waves. These numbers were typically higher than in the UK, Belgium, and the Netherlands throughout 2021, where the average number of contacts was fewer than 5 and occasionally dropped below 3 per day, and were substantially higher than in Germany where the average number of contacts stayed below 3 per day. It is important to note, however, that comparisons of the average number of contacts between countries should be treated with caution as the study periods often do not exactly match those in other countries. Wong et al. (2023) also showed that the numbers of contacts in children that attended school or not were similar in Switzerland. The reason for this could be that schools in Switzerland were only closed in spring 2020 and not during the study period. In addition, the school holidays varied regionally, i.e., also within the study population, and were relatively short. There were fewer interventions in schools than in workplaces, which likely led to smaller reduction in contacts in children compared to adults. Future contact surveys, including different seasons, will give insights on social contact behavior in Switzerland to better assess the risk of infection with SARS-CoV-2 and other respiratory diseases such as influenza. Additionally, Munday et al. (2023) suggested the use of contact data for forecasting incidences of infections.

We showed that the number of social contacts in Switzerland fell substantially from January 2021 to May 2022. Contacts remained below the pre-pandemic baseline despite the gradual lifting of contact restrictions during this period. Social contact surveys should be continued to monitor changes in social contact patterns by age group and over time. In addition to monitoring contact data, further studies are needed to clarify why the number of contacts remain lower than pre-pandemic levels. Finally, openly available contact data will be crucial for modeling studies on the transmission of respiratory infections in Switzerland and guiding future pandemic preparedness measures.

Declarations

NA

Ethics approval and consent to participate

The CoMix study protocols and questionnaires were approved by the local ethics committee of the Canton of Bern (project number 2020–02926). All methods were performed in accordance with regulations and informed consent of participants was obtained.

Author contributions

MR, NL, and CA conceived and designed the study. MR and CA performed the analysis and wrote the manuscript. All authors contributed to the interpretation of the results, commented on the manuscript, and approved the final version.

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CRediT authorship contribution statement

Martina L Reichmuth: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Christian L Althaus:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Leonie Heron:** Writing – review & editing, Project administration, Conceptualization. **Philippe Beutels:** Writing – review & editing, Supervision, Project administration, Funding acquisition. **Niel Hens:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Nicola Low:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of Competing Interest

All authors declare no competing interests.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.epidem.2024.100771.

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