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# Social contact patterns following the COVID-19 pandemic: a snapshot of post-pandemic behaviour from the CoMix study

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ABSTRACT

The COVID-19 pandemic led to unprecedented changes in behaviour. To estimate if these persisted, a final round of the CoMix social contact survey was conducted in four countries at a time when all societal restrictions had been lifted for several months. We conducted a survey on a nationally representative sample in the UK, Netherlands (NL), Belgium (BE), and Switzerland (CH). Participants were asked about their contacts and behaviours on the previous day. We calculated contact matrices and compared the contact levels to a pre-pandemic baseline to estimate $R_0$. Data collection occurred from 17 November to 7 December 2022. 7477 participants were recruited. Some were asked to undertake the survey on behalf of their children. Only 14.4 % of all participants reported wearing a facemask on the previous day. Self-reported vaccination rates in adults were similar for each country at around 86 %. Trimmed mean recorded contacts were highest in NL with 9.9 (95 % confidence interval [CI] 9.0–10.8) contacts per person per day and lowest in CH at 6.0 (95 % CI 5.4–6.6). Contacts at work were lowest in the UK (1.4 contacts per person per day) and highest in NL at 2.8 contacts per person per day. Other contacts were also lower in the UK at 1.6 per person per day (95 % CI 1.4–1.9) and highest in NL at 3.4 recorded per person per day (95 % CI 43.0–4.0). The next-generation approach suggests that $R_0$ for a close-contact disease would be roughly half pre-pandemic levels in the UK, 80 % in NL and intermediate in the other two countries. The pandemic appears to have resulted in lasting changes in contact patterns expected to have an impact on the epidemiology of many different pathogens. Further post-pandemic surveys are necessary to confirm this finding.

## 1. Background

Pandemics do not end with a bang (Wilson, 2022; Milne, 2018) but if you've seen one pandemic, then you've seen one pandemic (Osterholm, 2011)! The much-desired return to normality following the COVID-19 pandemic was always going to be difficult to determine both in what it means and when, if ever, it might happen. The expectation that things will be the same as before is also complicated by the pandemic leaving an indelible mark on society. The demonstration of the capacity of remote working, where possible, may mean that the number of people in offices will be lower. Socialising when ill could become taboo. Facemasks may become routine for some. Sentiments towards vaccines, perhaps more complex. One way we can assess the return is by conducting contact surveys (Hoang et al., 2019) to measure who mixes with

*Abbreviations:* CI, confidence interval; UK, United Kingdom; CH, Switzerland; BE, Belgium; NL, Netherlands.

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whom.

During the pandemic, the CoMix study recorded epidemiologically relevant (i.e. face-to-face) social interactions in representative samples of individuals from a number of European countries (21 countries in total collected data as part of the project) (Jarvis et al., 2020; Coletti et al., 2020; Steens et al., 2020; Gimma et al., 2022; Wong et al., 2023; Reichmuth et al., 2023; Backer et al., 2023). Different countries collected data at different points during the pandemic (Latsuzbaia et al., 2020; Liu et al., 2021; Trentini et al., 2022; Dorélien et al., 2023). However, the UK, Netherlands and Belgium initiated their surveys during the first lockdowns in spring 2020 and collected data more or less continually for about two years. Switzerland collected data between January 2021 and May 2022. The surveys were used to provide rapid insights into how social contact behaviour adapted as a result of the pandemic and the restrictions that governments put in place. Data collection was wound up at different times, at the latest by spring or early summer 2022, as pandemic-specific restrictions were being lifted across Europe.

These previous studies assessed the adaptation in behavior in periods of varying COVID-19 policies, quantifying the number of contacts in the population and providing crucial insights for assessing the impact of such policies. However, because of the different time windows of data collection, the variability of COVID-19 policies implementation, and potentially other factors such as, for example, epidemic impact, the results from the CoMix study highlighted that the relationship between, e.g. national policy and individual perceptions varied between countries (Wong et al. 2023; Wambua et al., 2023). In this study, we aim to overcome these limitations by analyzing social behavior in the same period of low COVID-19 related restrictions across four different countries. More specifically, we aim to quantify the number of contacts in the population after most of the COVID-19 restrictions have been lifted. While previous studies have aimed to assess contact patterns in an evolving epidemic scenario, here we aim to quantify post-pandemic behaviour. Moreover, we want to compare the estimates of contact patterns we measure with those measured prior to and during the pandemic, to test whether pre-pandemic values have been reached, to evaluate potential changes, and to discuss their most likely causes.

To do so, we return to measure epidemiologically relevant social contacts during late November and early December 2022 in the UK, Netherlands, Belgium, and Switzerland, using identical methods as for the main CoMix study. We compare the levels of mixing across the four countries and in different settings. We may not yet be at a stable post-pandemic period of behaviour, with adaptations still to come, but this study provides a bridge between how we behaved during 2020, the acute phase of the COVID-19 pandemic, and the evolving picture of where we might be heading in the years to come.

## 2. Methods

In what follows, we briefly describe the methodology we used. Some of the methods were initially designed for previous iterations of the CoMix surveys, and in that case we will also refer the reader to the original papers.

### 2.1. Ethics statement

Participation in this opt-in study was voluntary, and all analyses were carried out on anonymised data. The study was approved in the UK by the ethics committee of the London School of Hygiene & Tropical Medicine Reference number 21795. The study to collect CoMix data in Belgium was approved by the Ethics Committee of UZA with reference 3236 - BUN B3002020000054. The Medical Research Ethics Committee (MREC) NedMec confirmed that the Medical Research Involving Human Subjects Act (WMO) does not apply to the CoMix study in the Netherlands (research protocol number 22/917). Therefore an official approval of this study by the MREC NedMec is not required under the WMO. The study to collect CoMix data in Switzerland was approved by the ethics committee of the Canton of Bern (project number 2020–02926).

### 2.2. Study design

We conducted an online behavioural survey called CoMix, where individuals recorded details of direct contacts in the day prior to the survey. We defined a direct contact as anyone who was met in person and with whom at least a few words was exchanged, or anyone with whom the participants had any sort of skin-to-skin contact. Contacts of individuals under the age of 18 were collected by asking parents to answer on behalf of their child.

The design of the CoMix survey is based on the POLYMOD contact survey. The POLYMOD survey was a self-administered paper survey in the form of a daily diary recording participants' social contacts (Mossong et al., 2008). In the CoMix study, participants consented to self-report their social contacts made on the day prior to survey participation. Other survey questions in CoMix included participants' work attendance, self-reported risk status, use of facemasks, presence of recent symptoms, and vaccination history. Details of the CoMix study, including the protocol, methodology, and survey instrument, have been published previously (Jarvis et al., 2020; Gimma et al., 2022; Wong et al., 2023).

CoMix was conducted in 21 European countries between March 2020 and July 2022. In this paper, we present the final additional round of data collected between Nov 2022 and Dec 2022 in the UK, the Netherlands, Belgium, and Switzerland. In each study country, a nationally representative sample was recruited using quota sampling based on age (full population), gender, geographic region (NUTS2), and, socioeconomic status to reflect the distribution within the national population. The market research company Ipsos recruited participants through a combination of social media, web advertising, and email campaigns to meet quotas.

### 2.3. Study participants

The final round of CoMix ran from 17 November 2022 to 7 December 2022. Data were collected at similar times for all countries; starting first in the UK (17 Nov to 29 Nov), then the Netherlands (21 Nov to 3 Dec), Switzerland (22 Nov to 7 Dec), and finally Belgium (23 Nov to 5 Dec). As per prior rounds of CoMix and due to differing funding levels, the UK panel was double the size of the other countries with 2991 participants (Netherlands 1491, Switzerland 1495, Belgium 1500).

### 2.4. Data

#### 2.4.1. Reporting of contacts

The participants reported their contacts from the day prior to the survey in two ways: individual contacts and group contacts. Individual contacts were recorded by asking the participant to list each contact and their characteristics separately. Following this, we asked whether they had recorded all their contacts. If they had not, then they provided details of the total number of contacts they had at work, school, or other settings for the age groups 0–17, 18–59, and 60+, both overall and for physical contacts only ('group contacts'). They were also asked how often they met each contacted person, how much time was spent with them, and their relationship with the contacted person. Further details of the CoMix survey have been reported extensively previously (Jarvis et al., 2020; Coletti et al., 2020; Gimma et al., 2022; Wong et al., 2023).

#### 2.4.2. Demographic information

The survey captures information about participants' demographics. Participants' ages were grouped into categories of 0–4, 5–11, 12–17, 18–29, 30–39, 40–49, 50–59, 60–69, and 70 years and above. Participants were asked to report how they describe their gender, with the options of "Female", "Male", "In another way", or "Prefer not to answer". Participants were also asked about their household size.

#### 2.4.3. Risk perception, risk status, and risk mitigation

Participants reported about their uptake of risk mitigating activities and responded to statements regarding their perception of risk. Participants were asked to rate the following statements: (i) "I am likely to catch coronavirus"; (ii) "I am worried that I might spread coronavirus to someone who is vulnerable"; and (iii) "Coronavirus would be a serious illness for me". We named these three items *perceived susceptibility*, *perceived risk to the vulnerable* and *perceived severity,* analogously to previous work (Wambua et al., 2023). All these three items were measured using the Likert scale of "Strongly agree," "Tend to agree", "Neutral", "Tend to disagree" and "Strongly disagree". Participants self-reported whether they considered themselves to be high risk (*risk status*), whether they wore a face covering at least once on the prior day, and their COVID-19 vaccination status (*risk mitigation*).

#### 2.4.4. Presentation of COVID-like symptoms

Participants were asked about COVID-19-compatible symptoms during the 7 days prior to survey participation, with the option of reporting multiple answers. These symptoms included: fever or chills, cough, shortness of breath (or difficulty breathing), fatigue (or extreme tiredness), muscle or body aches or headache, congestion (or runny nose), and sore throat.

#### 2.4.5. Employment status, workplace status and attendance

Participants were asked to report whether they were employed, and if so, whether they were full time, part time, or self-employed. They reported whether their work place was open and whether they attended work on the day prior to responding to the survey (the day they reported contacts for).

### 2.5. Statistical analysis

R version 4.1.1 (R Core Team, 2017) was used for all analyses, and the code and data are available online (see Data Availability Statement). The code for the analyses conducted in this study is available at https://github.com/jarvisc1/cmix_post_pandemic.

### 2.6. Descriptive

We calculated the counts and percentages for contacts, risk perceptions, mitigations, symptoms, and employment related questions stratified by age, gender, household size, and day of the week. While parents answer as proxies for children in the study, we describe the designated child as the "participant" where applicable. We restricted the analysis to adults only for risk perception, mitigation, symptoms, and employment questions, as we consider the data to be more reliable than those reported for children by their parents. For risk perception (perceived susceptibility, perceived severity, and perceived risk to the vulnerable), we present the number and percentage of adults who strongly agreed with the statements asked.

### 2.7. Mean number of contacts

We calculated the mean number of contacts for each of the characteristics presented in the descriptive analysis. We used a cut-off value of 100 as the maximum for contacts and included the 'group contacts' in this analysis (see section "Reporting of contacts"). This means we counted any individual who reported more than 100 contacts as if they reported 100 contacts to reduce the weight of individuals reporting high numbers of contacts on the mean. Previous publications, specifically for the UK papers for CoMix have used a cut-off of 50 (Gimma et al., 2022). The value of 100 was chosen for two reasons, 1) Over 99.9 % of participants reported contacts of less than 100, 2) The previous publication of CoMix comparing 21 countries (Wong et al., 2023) used a cutt-off of 100, so for sake of consistency we used this threshold. We included in the supporting information an analysis with the threshold set to 300 contacts per day. For mean contacts by setting and country we calculated 95 % confidence intervals (95 % CI) using bootstrapping, similar to the approach used in a previous CoMix publication (Wong et al., 2023). For mean contacts by characteristics we present means with standard deviations, as this makes comparison easier with those presented in POLYMOD (Mossong et al., 2008) and in other social contact surveys (Hoang et al., 2019). As per previous studies (Jarvis et al., 2020; Coletti et al., 2020), the sample was also weighted by 2/7 for weekends and 5/7 for weekdays to account for differences in sampling of weekend and weekend days and the difference between weekend and weekday contacts. When comparing the average number of contacts between participants with different characteristics (e.g. females vs males respondents) we used the 2-sample Kolmogorov-Smirnof test to, with a p-value threshold for significance of 0.05.

### 2.8. Frequency and time spent with contacts

We explored types of behaviour with the frequency that participants met a contacted person, and with how long they spent with them. For this, we calculated the proportion of contacts that were physical, where a 2 metre distance was maintained, where a face-mask was used, and where they met outside. These were presented visually using stacked percentage bar charts. This approach was chosen as it allows for more direct comparison with the original POLYMOD paper (Mossong et al., 2008) which explored duration and frequency with physical contact. We extend that analysis to include more pandemic specific behaviours.

### 2.9. Contact matrices

For each country, we constructed age-stratified contact matrices for nine age groups (0–4, 5–11, 12–17, 18–29, 30–39, 40–49, 50–59, 60–69, and 70+ years old). For child participants and contacts, we did not record exact ages and therefore sampled from the reported age-group with a weighting consistent with the age distribution of contacts for the participants' own age group, according to the POLYMOD survey methods (Mossong et al., 2008). Observations were weighted by 2/7 for weekends and 5/7 for weekdays and population weights were used to correct for potential under/over representation of age classes. We fitted a negative binomial model censored to 50 per matrix cell, due to dispersion of the reported number of contacts, to calculate mean contacts between each participant and contact age group. The value for censoring was chosen to be consistent and to ease comparison with previously published contact matrix estimates (Gimma et al., 2022; Munday et al., 2021). To find the population normalised reciprocal contact matrix, we first multiplied the columns of the matrix by the mean-normalised proportion of the relevant country population in each age-group (Mossong et al., 2008; Klepac et al., 2020). Then we took the cross-diagonal mean of each element of the contact matrix. Finally, we divided the resulting symmetrical matrix by the population mean-normalised proportion of the country's population in each age-group.

### 2.10. Comparison to pre-pandemic and pandemic contact levels

We estimated the potential relative change in basic reproduction number $R_0$ of an infection (that spreads along the contacts, assuming everyone would be susceptible to that infection) due to change in contact levels compared to pre-pandemic levels by calculating the ratio of the dominant eigenvalues of the CoMix matrices to those from POLYMOD, using the same approach as previously published (Jarvis et al., 2020). This approach, based on the next-generation-matrix approach (Diekmann et al., 2010), is based on the assumption that all other infection-related factors are the same between the two situations that are compared and, therefore, can be cancelled out in the ratio of Next-generation-matrices.

Switzerland did not participate in the POLYMOD study and we therefore used the projected synthetic contact matrix for Switzerland from Prem et al. (2017). As a sensitivity analysis, we also provide the case where the pre-pandemic data for Switzerland was computed as the average of the eight POLYMOD countries. Uncertainty for the ratios was provided by calculating the dominant eigenvalues from 1000 bootstrap samples for the CoMix matrices for each country and the dominant eigenvalues from 1000 bootstrap samples for the POLYMOD matrices for each country.

We further compared POLYMOD to the earliest estimates of contact levels during the 1st lockdown in the UK and BE. This estimate was not repeated for Switzerland and the Netherlands as data from children in these countries was not collected until later (December 2020).

**Table 1**
Participants characteristics.

| Category | Value | All | UK | BE | NL | CH |
|---|---|---|---|---|---|---|
| All | | 7477 | 2991 | 1500 | 1491 | 1495 |
| Adult | | 6040 (80.8 %) | 2388 (79.8 %) | 1200 (80.0 %) | 1215 (81.5 %) | 1237 (82.7 %) |
| Child | | 1437 (19.2 %) | 603 (20.2 %) | 300 (20.0 %) | 276 (18.5 %) | 258 (17.3 %) |
| Age group (Children) | 0–4 | 213 (15.4 %) | 85 (14.5 %) | 33 (11.3 %) | 42 (16.3 %) | 53 (21.7 %) |
| | 5–11 | 519 (37.6 %) | 222 (37.8 %) | 110 (37.7 %) | 81 (31.4 %) | 106 (43.4 %) |
| | 12–17 | 650 (47.0 %) | 281 (47.8 %) | 149 (51.0 %) | 135 (52.3 %) | 85 (34.8 %) |
| Age group (Adult) | 18–29 | 1021 (17.1 %) | 402 (16.8 %) | 212 (17.7 %) | 205 (17.3 %) | 202 (16.9 %) |
| | 30–39 | 1028 (17.2 %) | 440 (18.4 %) | 196 (16.3 %) | 188 (15.8 %) | 204 (17.1 %) |
| | 40–49 | 930 (15.6 %) | 349 (14.6 %) | 189 (15.8 %) | 193 (16.3 %) | 199 (16.7 %) |
| | 50–59 | 1016 (17.0 %) | 431 (18.0 %) | 206 (17.2 %) | 190 (16.0 %) | 189 (15.8 %) |
| | 60–69 | 1223 (20.5 %) | 494 (20.7 %) | 262 (21.8 %) | 264 (22.2 %) | 203 (17.0 %) |
| | 70+ | 752 (12.6 %) | 272 (11.4 %) | 135 (11.2 %) | 147 (12.4 %) | 198 (16.6 %) |
| Gender | Female | 3781 (50.8 %) | 1564 (52.5 %) | 733 (49.0 %) | 759 (51.1 %) | 725 (48.7 %) |
| | Male | 3667 (49.2 %) | 1414 (47.5 %) | 762 (51.0 %) | 726 (48.9 %) | 765 (51.3 %) |
| | Other | 29 | 13 | 5 | 6 | 5 |
| Household size | 1 | 1508 (20.2 %) | 538 (18.0 %) | 295 (19.7 %) | 339 (22.7 %) | 336 (22.5 %) |
| | 2 | 2520 (33.7 %) | 1062 (35.5 %) | 473 (31.5 %) | 487 (32.7 %) | 498 (33.3 %) |
| | 3–5 | 3292 (44.0 %) | 1323 (44.2 %) | 699 (46.6 %) | 638 (42.8 %) | 632 (42.3 %) |
| | 6+ | 157 (2.1 %) | 68 (2.3 %) | 33 (2.2 %) | 27 (1.8 %) | 29 (1.9 %) |
| Day of week | Mon | 856 (11.4 %) | 357 (11.9 %) | 41 (2.7 %) | 111 (7.4 %) | 347 (23.2 %) |
| | Tue | 1663 (22.2 %) | 676 (22.6 %) | 570 (38.0 %) | 26 (1.7 %) | 391 (26.2 %) |
| | Wed | 1704 (22.8 %) | 950 (31.8 %) | 256 (17.1 %) | 322 (21.6 %) | 176 (11.8 %) |
| | Thu | 848 (11.3 %) | 419 (14.0 %) | 117 (7.8 %) | 234 (15.7 %) | 78 (5.2 %) |
| | Fr | 366 (4.9 %) | 24 (0.8 %) | 132 (8.8 %) | 88 (5.9 %) | 122 (8.2 %) |
| | Sat | 244 (3.3 %) | 32 (1.1 %) | 67 (4.5 %) | 54 (3.6 %) | 91 (6.1 %) |
| | Sun | 1796 (24.0 %) | 533 (17.8 %) | 317 (21.1 %) | 656 (44.0 %) | 290 (19.4 %) |
| Perceived susceptibility (Adults) | Strongly agree | 453 (7.6 %) | 151 (6.3 %) | 89 (7.4 %) | 122 (10.3 %) | 91 (7.6 %) |
| | Tend to agree | 1271 (21.3 %) | 515 (21.6 %) | 236 (19.7 %) | 265 (22.3 %) | 255 (21.3 %) |
| | Neither agree nor disagree | 2143 (35.9 %) | 914 (38.3 %) | 455 (37.9 %) | 420 (35.4 %) | 354 (29.6 %) |
| | Tend to disagree | 1129 (18.9 %) | 493 (20.6 %) | 188 (15.7 %) | 160 (13.5 %) | 288 (24.1 %) |
| | Strongly disagree | 693 (11.6 %) | 206 (8.6 %) | 154 (12.8 %) | 159 (13.4 %) | 174 (14.6 %) |
| | Don't know | 281 (4.7 %) | 109 (4.6 %) | 78 (6.5 %) | 61 (5.1 %) | 33 (2.8 %) |
| Perceived severity (Adults) | Strongly agree | 571 (9.6 %) | 204 (8.5 %) | 133 (11.1 %) | 159 (13.4 %) | 75 (6.3 %) |
| | Tend to agree | 1288 (21.6 %) | 526 (22.0 %) | 266 (22.2 %) | 280 (23.6 %) | 216 (18.1 %) |
| | Neither agree nor disagree | 1514 (25.4 %) | 659 (27.6 %) | 330 (27.5 %) | 276 (23.3 %) | 249 (20.8 %) |
| | Tend to disagree | 1351 (22.6 %) | 569 (23.8 %) | 252 (21.0 %) | 220 (18.5 %) | 310 (25.9 %) |
| | Strongly disagree | 1001 (16.8 %) | 342 (14.3 %) | 168 (14.0 %) | 216 (18.2 %) | 275 (23.0 %) |
| | Don't know | 245 (4.1 %) | 88 (3.7 %) | 51 (4.2 %) | 36 (3.0 %) | 70 (5.9 %) |
| Perceived risk to the vulnerable (Adults) | Strongly agree | 751 (12.6 %) | 372 (15.6 %) | 92 (7.7 %) | 157 (13.2 %) | 130 (10.9 %) |
| | Tend to agree | 1675 (28.1 %) | 829 (34.7 %) | 239 (19.9 %) | 315 (26.5 %) | 292 (24.4 %) |
| | Neither agree nor disagree | 1524 (25.5 %) | 517 (21.6 %) | 444 (37.0 %) | 302 (25.4 %) | 261 (21.8 %) |
| | Tend to disagree | 1025 (17.2 %) | 409 (17.1 %) | 185 (15.4 %) | 177 (14.9 %) | 254 (21.3 %) |
| | Strongly disagree | 827 (13.9 %) | 228 (9.5 %) | 157 (13.1 %) | 201 (16.9 %) | 241 (20.2 %) |
| | Don't know | 168 (2.8 %) | 33 (1.4 %) | 83 (6.9 %) | 35 (2.9 %) | 17 (1.4 %) |
| Risk mitigation (Adults) | Face mask | 888 (14.7 %) | 395 (16.5 %) | 191 (15.9 %) | 82 (6.7 %) | 220 (17.8 %) |
| | Vaccinated | 5284 (87.5 %) | 2211 (92.6 %) | 1044 (87.0 %) | 1044 (85.9 %) | 985 (79.6 %) |
| | High risk | 1484 (24.9 %) | 439 (18.6 %) | 347 (29.3 %) | 372 (31.2 %) | 326 (26.8 %) |
| Symptoms (Adults) | Fever | 253 (4.2 %) | 90 (3.8 %) | 47 (3.9 %) | 46 (3.9 %) | 70 (5.9 %) |
| | Cough | 860 (14.4 %) | 351 (14.7 %) | 153 (12.8 %) | 157 (13.2 %) | 199 (16.7 %) |
| | Shortness of breath | 317 (5.3 %) | 152 (6.4 %) | 50 (4.2 %) | 67 (5.6 %) | 48 (4.0 %) |
| | Congestion | 919 (15.4 %) | 342 (14.3 %) | 180 (15.0 %) | 198 (16.7 %) | 199 (16.7 %) |
| | Sore throat | 566 (9.5 %) | 211 (8.8 %) | 118 (9.8 %) | 106 (8.9 %) | 131 (11.0 %) |
| | Fatigue or tiredness | 570 (9.5 %) | 256 (10.7 %) | 97 (8.1 %) | 115 (9.7 %) | 102 (8.5 %) |
| | Any symptoms | 2385 (39.9 %) | 933 (39.1 %) | 462 (38.5 %) | 473 (39.8 %) | 517 (43.3 %) |
| Employed (Adults) | Full time | 2180 (36.5 %) | 904 (37.9 %) | 453 (37.8 %) | 388 (32.7 %) | 435 (36.4 %) |
| | Part time | 876 (14.7 %) | 345 (14.4 %) | 111 (9.2 %) | 234 (19.7 %) | 186 (15.6 %) |
| | Self employed | 298 (5.0 %) | 155 (6.5 %) | 37 (3.1 %) | 51 (4.3 %) | 55 (4.6 %) |
| | Unemployed | 1128 (18.9 %) | 419 (17.5 %) | 273 (22.8 %) | 267 (22.5 %) | 169 (14.1 %) |
| | Retired | 1488 (24.9 %) | 565 (23.7 %) | 326 (27.2 %) | 247 (20.8 %) | 350 (29.3 %) |
| Workplace open (Employed Adults) | closed | 304 (9.0 %) | 155 (11.0 %) | 48 (8.0 %) | 51 (7.5 %) | 50 (7.5 %) |
| | open | 3056 (91.0 %) | 1255 (89.0 %) | 552 (92.0 %) | 630 (92.5 %) | 619 (92.5 %) |
| Attended work (Employed Adults, with workplace open) | Yes | 1675 (61.7 %) | 641 (60.3 %) | 307 (61.5 %) | 299 (52.3 %) | 428 (73.8 %) |

*Bootstrapped mean and 95 % percentage confidence interval from 1000 samples. Sample weighted by 2/7 for weekends and 5/7 for weekdays.

### 2.11. Comparison of post-pandemic and pandemic behaviours

We compared several of the measurements made during this final round of CoMix to those previously published from the prior rounds of the survey to frame the current findings in relation to those during the pandemic. We provide an exploratory but non-comprehensive comparison to reduce the burden for the reader to compare across multiple publications.

## 3. Results

### 3.1. Participant characteristics

Overall, we recorded observations on 7477 participants who reported 74,534 contacts between 16 November 2022 and 6 December 2022 in the UK, Belgium, Netherlands, and Switzerland (Table 1). Just under 20 % (1336) were proxy respondents (i.e. the survey was completed by parents on behalf of children), and 6141 were adults. The UK has the highest number of participants at 2991, almost double the number of the other countries. Age representativity was good in all four countries (see figure S1), with the highest deviation from population distributions observed (~5 %) in the 60–69 and 70+ age categories.

The age distributions were broadly similar across the four countries, with Switzerland the most different with slightly more over 70 s and fewer 60–69, and more 5–11 s and fewer 12–17 year olds. There were 3781 (50.8 %) females and 3667 (49.2 %) males, with a similar roughly equal split in all countries. The majority of households consisted of 3–5 people in total with less than 2.5 % of participants in any country being in a household size of six or more. Contact data were collected every day of the week for all countries, though some days had lower participation, such as 24 (0.8 %) and 32 (1.1 %) responses in the UK on Friday and Saturday, 41 (2.7 %) in Belgium on Monday, and 26 (1.7 %) in the Netherlands on Tuesdays.

### 3.2. Risk perception

Overall, 7.6 % of the sample (ranging from 6.2 % in the UK to 10.3 % in the Netherlands) strongly agreed that they were at risk of catching coronavirus, and 9.5 % strongly agreed that they were at high risk of severe disease if they did catch coronavirus (ranging from 6.3 % in Switzerland to 13.4 % in the Netherlands). A slightly higher fraction (12.4 %) strongly agreed that they were likely to spread the virus to someone vulnerable, varying from 7.7 % in Belgium to 15.3 % in the UK.

### 3.3. Risk mitigation

Only 14.4 % of participants reported wearing a facemask on the previous day. The Netherlands had the lowest with 6.7 % participants wearing a facemask and Switzerland the highest with 17.8 % (Table 1). Self-reported vaccination in adults was similar for each country at around 85 % vaccinated. The UK had the lowest percentage of people self-reporting as being high risk at 17.2 % versus 31.2 % in the Netherlands.

### 3.4. Symptoms

Nearly 40 % of participants reported at least one of the following symptoms: fever or chills, cough, shortness of breath (or difficulty breathing), fatigue (or extreme tiredness), muscle or body aches or headache, congestion (or runny nose), and sore throat.

### 3.5. Employment

Approximately 43 % of adult participants were employed, though this includes individuals who may be retired as unemployed in the denominator. Of those who were employed, the majority (60–80 %) in each country were in full time employment, and around 5 % were self employed. For those in employment the vast majority (~90 %) reported that their workplaces were open and around two thirds attended work in person on the day they made their contacts (Table 1).

### 3.6. Mean contacts by country and setting

Participants from the Netherlands recorded considerably more contacts than the other three countries with 9.9 (95 % CI 9.0–10.8) contacts per person per day, as compared to 6.5 (95 % CI 6.0–7.0, p-value<0.05) contacts in the UK, 6.7 (95 % CI 6.0–7.3, p-value<0.05) in Belgium and 6.0 (95 % CI 5.4–6.6, p-value<0.05) in Switzerland. (Table 2). This pattern was also seen for adults (8.8, 95 % CI 7.9–9.8 for adults in the Netherlands) with all comparisons with other countries significant (p-value<0.05) and for children (14.8, 95 % CI 12.6–16.8 for children in the Netherlands) only in comparison with Switzerland (p-value<0.05). As well as overall contacts, we measured contacts for the four settings of home, work, school, and other. Contacts at home were very similar between the countries, with an average of about 1.5 contacts per person per day recorded, which is consistent with the household sizes seen in Table 1 (a mean of 2.6 overall for the study). Contacts at work for adults were lowest in the UK (a mean of 1.8 contacts recorded per person per day, 95 % CI 1.4–2.2) and highest in the Netherlands at 3.3 contacts per person per day (95 % CI 2.8–4.0). The survey average for work contacts was 2.3, smaller than the value of 3.3 measured in the POLYMOD study. Other contacts (mostly in social settings) were also lowest in the UK at 1.6 per person per day (95 % CI 1.4–1.9) and highest in the Netherlands at 3.3 recorded per person per day (95 % CI 2.7–4.0). The average number of contacts in other settings (2.3 contacts per person per day) is considerably lower than the average value from the POLYMOD survey (5.0 contacts per person per day).

Table S2 presents results for the analysis with a higher threshold value on the contacts (300 instead of 100 contacts per person per day). The average number of contacts increased the most in the Netherlands (from 9.9 to 11.6), with UK, Belgium and Switzerland showing an increase of roughly one contact on average per day (from 6.5 to 7.2 for the UK, from 6.7 to 7.3 for Belgium and 6.0–6.4 for Switzerland).

### 3.7. Frequency and time spent with contacts

Higher frequency contacts (1–2 days) were more likely to include physical touch (> 50 %) compared to less frequent contacts (e.g. never met before<25 %) (Fig. 1). Similarly, physical contact was more likely for those spending 4 hours or more with a contact, with the proportion of physical contacts observed in the data decreasing as the duration of contact decreased (Fig. 2).

The percentage of contacts met every 1–2 days that were physical was similar to those seen in POLYMOD for the UK, Netherlands, and Belgium (Fig. 1). Though for those meeting less often, the percentage of physical contacts appears lower than POLYMOD for the UK and Belgium but similar for the Netherlands (Fig. 1). The patterns were somewhat consistent for time spent with contacts and percentage of physical contact, the Netherlands had near identical percentages, Belgium had slightly lower for all but the shortest durations of contacts, and the UK had slightly lower for all but the longest duration of contacts (Fig. 2).

The percentage of participants staying at least 2 ms away was slightly higher in the Netherlands though still less than 25 % for all countries, with only those who were met every 1–2 days being less likely to wear a mask compared to when meeting a less frequent contact (Fig. 1). Maintenance of a two metres distance appears to be more common for shorter interactions (Fig. 2),

Mask wearing was infrequent (<15 %) in all countries and for all types of contact, with participants less likely to wear a mask when meeting someone often and for shorter periods (<5 m) or longer (4 h+) periods of time (Figs. 1 and 2).

The fraction of contacts who met outside were similar for all

**Table 2**
Mean daily contacts per participant by country and setting. Polymod data (Mossong et al., 2008) is reported as Pmod.

| Sample | variable | UK | UK (Pmod) | BE | BE (Pmod) | NL | NL (Pmod) | CH |
|---|---|---|---|---|---|---|---|---|
| All | | | | | | | | |
| | All | 6.5 (6.0–7.0) | 12.0 (11.6–12.5) | 6.7 (6.0–7.4) | 12.1 (11.4–12.8) | 9.9 (9.0–10.7) | 14.1 (13.4–14.8) | 6.0 (5.4–6.6) |
| | Home | 1.5 (1.5–1.6) | 3.9 (3.8–4.1) | 1.5 (1.5–1.6) | 3.3 (3.1–3.5) | 1.6 (1.5–1.7) | 3.5 (3.2–3.7) | 1.5 (1.4–1.5) |
| | Work | 1.4 (1.2–1.7) | 2.0 (1.7–2.3) | 1.7 (1.3–2.1) | 2.2 (1.8–2.6) | 2.8 (2.2–3.4) | 2.5 (2.1–2.8) | 1.6 (1.3–1.9) |
| | School | 2.2 (1.9–2.6) | 2.9 (2.5–3.3) | 1.7 (1.3–2.1) | 1.6 (1.3–2.0) | 3.0 (2.5–3.5) | 3.6 (3.1–4.1) | 1.1 (0.8–1.4) |
| | Other | 1.6 (1.4–1.9) | 3.8 (3.6–4.1) | 2.2 (1.9–2.6) | 5.6 (5.2–6.1) | 3.4 (3.0–4.0) | 5.5 (5.1–6.0) | 2.2 (1.9–2.6) |
| Adults | | | | | | | | |
| | All | 4.6 (4.1–5.0) | 10.8 (10.2–11.3) | 5.5 (4.8–6.3) | 12.3 (11.3–13.2) | 8.8 (7.8–9.8) | 12.2 (11.4–13.0) | 5.4 (4.8–5.9) |
| | Home | 1.3 (1.2–1.3) | 3.6 (3.4–3.8) | 1.3 (1.3–1.4) | 3.1 (2.9–3.4) | 1.4 (1.3–1.5) | 3.0 (2.8–3.3) | 1.3 (1.2–1.4) |
| | Work | 1.8 (1.4–2.2) | 3.0 (2.6–3.5) | 2.1 (1.6–2.7) | 3.3 (2.7–3.9) | 3.3 (2.8–4.0) | 3.6 (3.1–4.2) | 1.9 (1.5–2.3) |
| | School | 0.4 (0.2–0.5) | 0.6 (0.5–0.8) | 0.5 (0.3–0.8) | 0.6 (0.4–0.8) | 1.8 (1.4–2.3) | 0.5 (0.3–0.8) | 0.5 (0.3–0.7) |
| | Other | 1.5 (1.3–1.8) | 3.9 (3.6–4.3) | 2.0 (1.6–2.4) | 5.7 (5.2–6.4) | 3.3 (2.7–3.9) | 5.7 (5.1–6.4) | 2.1 (1.7–2.5) |
| Children | | | | | | | | |
| | All | 13.0 (11.5–14.6) | 14.3 (13.3–15.1) | 10.5 (8.6–12.4) | 11.8 (10.6–13.0) | 14.8 (12.7–17.0) | 18.0 (16.5–19.4) | 9.1 (7.2–11.1) |
| | Home | 2.5 (2.4–2.6) | 4.6 (4.3–4.9) | 2.2 (2.1–2.4) | 3.5 (3.2–3.8) | 2.6 (2.4–2.8) | 4.3 (3.9–4.6) | 2.1 (1.9–2.3) |
| | Work | 0.2 (0.1–0.5) | 0.3 (0.1–0.4) | 0.1 (0.0–0.3) | 0.1 (0.0–0.2) | 0.3 (0.1–0.4) | 0.3 (0.1–0.7) | 0.4 (0.2–0.7) |
| | School | 8.6 (7.4–9.9) | 6.9 (6.0–7.7) | 5.5 (4.3–6.8) | 3.7 (2.8–4.6) | 8.2 (6.8–9.7) | 9.3 (8.0–10.5) | 3.9 (2.9–5.2) |
| | Other | 2.0 (1.5–2.5) | 3.6 (3.1–4.0) | 3.1 (2.2–4.0) | 5.5 (4.7–6.2) | 3.9 (3.1–4.9) | 5.6 (4.9–6.3) | 3.1 (2.2–4.2) |

frequency of contact and across the four countries (Fig. 1). There was a slight trend (in each country) for longer-duration contacts to have occurred outside (Fig. 2).

### 3.8. Mean contacts by characteristics

#### 3.8.1. Age, gender, households size

The reported mean contacts for school-aged children (5–11 and 12–17 years of age) in the UK and Netherlands were similar at around 14 contacts per person per day, whereas Belgium and Switzerland were lower with both at around 10 contacts (Table 3). This pattern was different amongst adults, with the UK reporting the lowest levels of contacts in most adult age groups. Young adults (18–29 years old) in Belgium and the Netherlands reported the highest mean contact rates (7.6 and 10.4 per person per day, respectively, as compared to 4.8 in the UK and 5.9 in Switzerland).

Females reported on average more contacts than males in UK (7.1 vs 5.1, p-value<0.05), the Netherlands (9.7 vs 8.9, p-value<0.05), and Switzerland (6.3 vs 5.5, not significant), the opposite being true for Belgium (6.2 vs 6.9, not significant). As expected, household size was positively correlated with the number of reported contacts with some slight departures from this pattern in Belgium and the Netherlands.

#### 3.8.2. Day of the week

Contacts by day show a high variability between days with far lower contacts on the weekend and also on a day either side of the weekend for the UK (Friday) and Belgium and the Netherlands (Monday) (Table 3). However, these differences are not statistically significant. When assessing the impact of weekdays vs weekends, results are significant only in the case of the Netherlands.

#### 3.8.3. Risk mitigation

Those who reported wearing a facemask tended to report fewer contacts in all countries other than Belgium, however results were significant (i.e. p-value < 0.05) only for The Netherlands and Switzerland. Those self reporting as high risk reported significantly (i.e. p-value<0.05) lower contacts across all four countries. Those who were vaccinated tended to report significantly (i.e. p-value<0.05) fewer contacts than those who said they had not been vaccinated (except for in Belgium), though it should be stressed that this is a univariate analysis and the unvaccinated tended to be younger in age.

#### 3.8.4. Employment

Number of contacts were highest for employed people in the Netherlands, with self employed people in Belgium and the Netherlands reporting about 20 contacts per person per day. With the vast majority of workplaces being open now, contacts still tended to be higher for people whose workplace was open. As expected, there was still a considerable difference in the mean contacts for those who attended work versus those who did not.

### 3.9. Contact matrices and changes in pre-pandemic and post-pandemic $R_0$

Contact matrices were similar across the four nations, with high rates of recorded contacts along the leading diagonal (suggesting that contact is age-assortative) and the highest rates of recorded contacts being for children (Fig. 3A). The Netherlands had the highest levels of contacts overall. There were comparatively high levels of contact between over 70 s in all countries, except Belgium.

Using the next-generation matrix approach (Diekmann et al., 2010), these contact matrices can be used to estimate $R_0$ for close-contact infections spread through physical or conversational contacts (as measured here), assuming that everyone is susceptible to infection. In constructing the next generation matrix several features of the pathogen and the host (e.g. host susceptibility (Franco et al., 2022); Davies et al., 2020) have not been included. This approach is particularly useful for comparing different behaviours: under the assumption that the disease parameters are independent of age and the same, one can compute the relative change in the corresponding $R_0$ that is due to changes in behaviour (Hens et al., 2009). The relative change in $R_0$ for reported contacts, compared to contacts at pre-pandemic levels (as measured in the POLYMOD study) is shown in Fig. 3B (Table S1). The reduction in contacts, compared with POLYMOD, would lead to a significant reduction in the reproduction number $R_0$ in each of the four countries, with the UK's $R_0$ being roughly half of pre-pandemic levels and the Netherlands about 80 % of the pre-pandemic level (with the other two countries being intermediate). For context, Fig. 3B also shows the relative reduction in $R_0$ during the first lockdown in the UK, which was 25 % of the pre-pandemic level and Belgium which was 20 % of pre-pandemic levels (Fig. 3B and Table S1) (Coletti et al., 2020). Using the contact matrix generated by an average of the POLYMOD countries instead of the projected contact matrix from Prem et al (Prem et al., 2017). leads to comparable results (FIgure SI1).

### 3.10. Comparison of post-pandemic and pandemic behaviours and contacts

In this section, comparisons are made between the results from this round and those found for the UK, Netherlands, Belgium, and Switzerland in the analysis of the 2-year 21 country study by Wong et al (Wong et al., 2023).

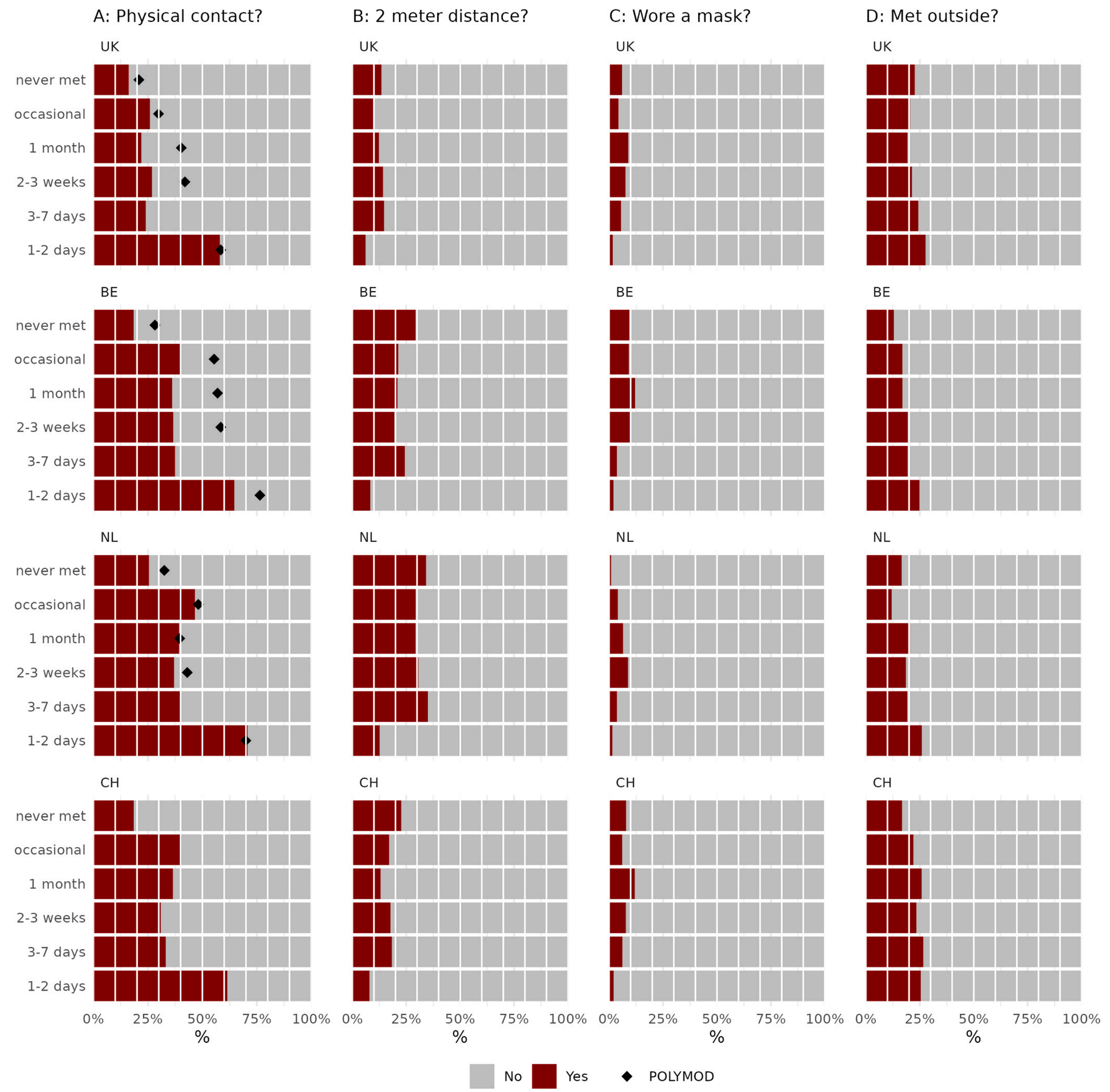


**Fig. 1.** Percentages of contacts that: A involved physical contact, B happened at a distance of more than two metres, C happened with the participant wearing a mask, D happened outdoors. Contacts are stratified by the frequency of meeting the contact and by country. The black point marks the corresponding value from the POLYMOD (Mossong et al., 2008) study, when available.

#### 3.10.1. *Risk and symptoms*

It appears that risk perceptions may have slightly changed since the pandemic with participants reporting a slightly higher belief that they will catch coronavirus (6–10 % versus 4–5 % in Wong), and a lower concern that it would be a serious illness for them (6–13 % versus 14–25 % in Wong), or that they will pass it on to someone considered vulnerable (8–15 % versus 19–26 % in Wong).

The percentage of individuals wearing facemasks (7–18 %) were considerably lower than levels measured in each individual country over the course of the pandemic (UK, 58.2 %, BE 61.4 %, NL 34.3 %, CH 76.7 %) (Wong et al., 2023).

The percentage of participants reporting at least one symptom (38–43 %) was quite a bit higher than reported over the two years of the pandemic which was between 21 % and 26 % (Wong et al., 2023). (Table 1 in this paper versus Table 1 in Wong et al (Wong et al., 2023).).

### 3.11. *Contacts*

The mean contacts measured in this survey were somewhat higher at between 6 and 10 for the mean contacts for the four countries compared to 3–4 contacts per day measured during the pandemic (Wong et al., 2023). Apart from a general increase in the level of contacts the main change appears to be in those 70+, an age group with very few contacts made during the pandemic, especially in the UK (see Figure 6 A in Gimma et al (Gimma et al., 2022).). In contact matrices measured during the pandemic in the UK, those aged 70 or older never had more than 1

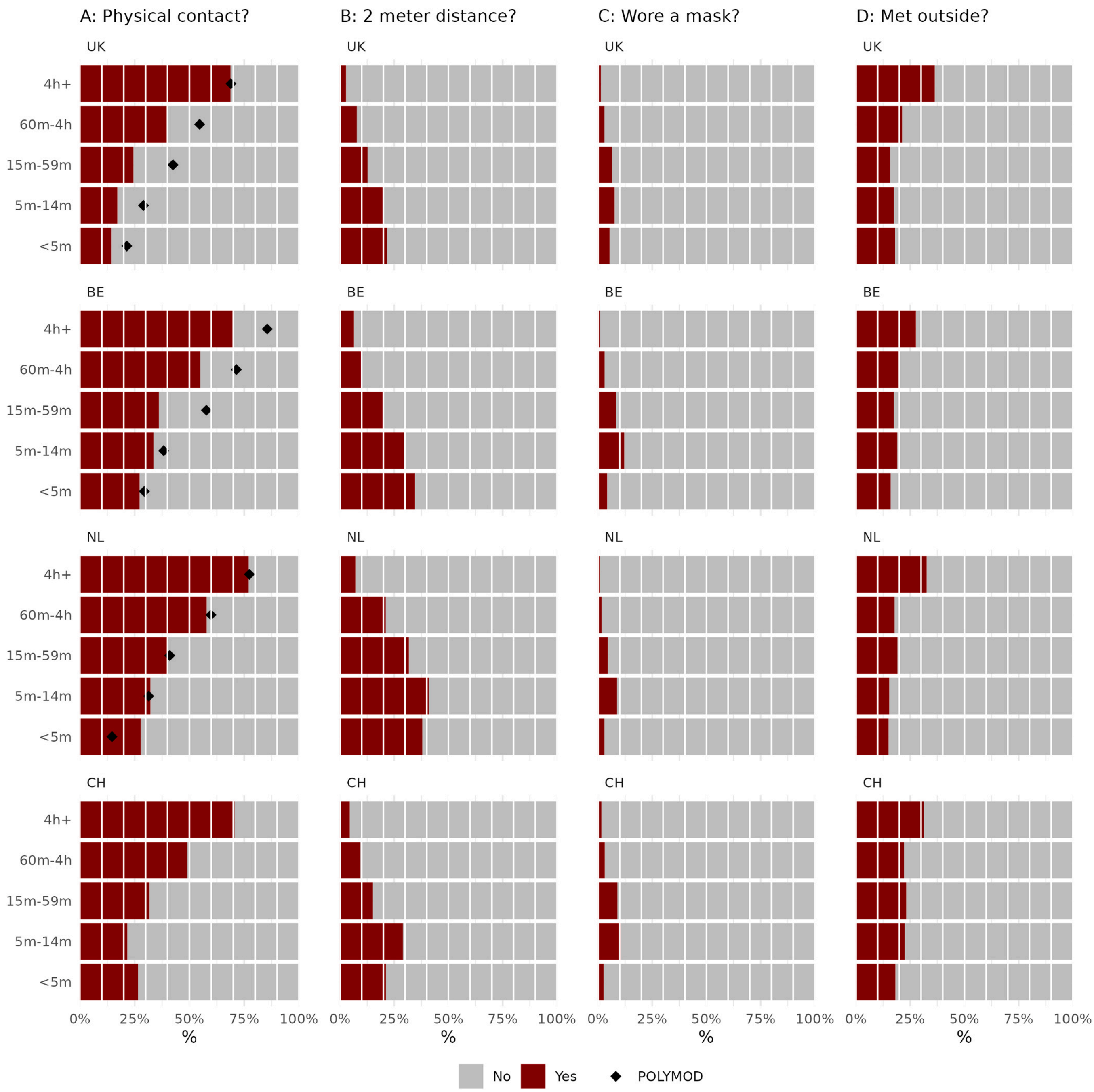


**Fig. 2.** Percentages of contacts that: A involved physical contact, B happened at a distance of more than two metres, C happened with the participant wearing a mask, D happened outdoors. Contacts are stratified by the duration of the contact and by country. The black point marks the corresponding value from the POLYMOD (Mossong et al., 2008) study, when available.

contact on average with those also aged 70+ and less than 0.4 for contacts with other age groups. In contrast, we estimate a value of 1.7 for 70+ year olds mixing with 70+ year olds and values as high as 0.7 for mixing with other age groups.

## 4. Discussion

We estimate that contact levels have increased compared to those measured during the pandemic but still remain lower than those measured prior to the pandemic. These reduced levels are likely to have a big impact on transmission with a reduction of $R_0$ of 20–50 % compared to pre-pandemic levels across the four nations. The consequences of this change in behaviour extends well beyond Covid and would be expected to have an impact on a range of infections that are spread person-to-person.

The use of facemasks has dropped considerably compared to the levels measured during the pandemic. We estimated around 15 % of people wore a face mask on the day of the study across the four countries which is considerably lower than the 64 % average observed from the CoMix study during the pandemic across 21 European countries (Wong et al., 2023).

Contacts amongst the individuals over the age of 70 were consistently low during the pandemic and we observed a bounce back in the number of contacts over 70 s make, especially in social settings.

Contact patterns were broadly similar across the four countries, with the Netherlands generally reporting a higher level of contacts. During

**Table 3**
Mean daily contacts per participant by characteristics.

| Category | Value | UK | BE | NL | CH |
|---|---|---|---|---|---|
| All | Mean (SD) | 6.1 (13.6) | 6.5 (13.5) | 9.2 (17.1) | 5.8 (11.3) |
| Adult | | 4.4 (11.2) | 5.6 (12.5) | 8.2 (16.8) | 5.2 (10.0) |
| Child | | 13.0 (19.3) | 10.4 (16.2) | 14.1 (17.6) | 9.0 (15.9) |
| Age group (Children) | 0–4 | 9.0 (14.9) | 11.8 (14.9) | 12.4 (12.6) | 6.2 (10.3) |
| | 5–11 | 15.1 (19.6) | 11.5 (16.7) | 14.3 (17.7) | 10.6 (18.5) |
| | 12–17 | 13.1 (20.4) | 9.8 (16.4) | 15.4 (19.4) | 9.7 (16.4) |
| Age group (Adult) | 18–29 | 4.6 (10.5) | 7.6 (16.1) | 10.4 (22.1) | 5.9 (10.3) |
| | 30–39 | 4.7 (12.7) | 5.8 (12.6) | 7.5 (13.1) | 6.7 (12.3) |
| | 40–49 | 4.5 (10.8) | 6.9 (15.7) | 8.5 (16.2) | 5.6 (9.9) |
| | 50–59 | 5.9 (15.4) | 5.5 (12.5) | 8.4 (17.6) | 5.3 (12.0) |
| | 60–69 | 2.7 (3.6) | 3.9 (8.1) | 7.0 (15.7) | 3.6 (6.8) |
| | 70+ | 4.0 (10.5) | 3.3 (5.2) | 5.5 (11.7) | 3.3 (6.4) |
| Gender | Female | 7.1 (15.5) | 6.2 (12.8) | 9.7 (17.8) | 6.3 (12.3) |
| | Male | 5.1 (11.3) | 6.9 (14.1) | 8.9 (16.3) | 5.5 (10.4) |
| Household size | 1 | 3.8 (13.7) | 3.7 (11.1) | 4.7 (12.1) | 3.6 (8.2) |
| | 2 | 4.4 (11.2) | 5.1 (11.0) | 8.0 (16.8) | 5.1 (10.9) |
| | 3–5 | 8.2 (15.0) | 8.7 (15.6) | 12.7 (19.0) | 7.1 (11.9) |
| | 6+ | 10.4 (14.2) | 6.9 (6.2) | 8.8 (11.5) | 17.5 (22.2) |
| Day of week | Mon | 10.1 (16.8) | 4.8 (5.9) | 5.6 (9.0) | 5.8 (11.5) |
| | Tue | 5.6 (13.7) | 5.5 (11.9) | 17.2 (29.0) | 5.9 (9.9) |
| | Wed | 6.4 (14.1) | 10.2 (16.7) | 10.7 (18.7) | 7.5 (13.5) |
| | Thu | 7.1 (14.5) | 7.2 (13.1) | 10.6 (18.1) | 5.0 (7.6) |
| | Fr | 2.2 (2.6) | 6.1 (13.4) | 15.2 (22.7) | 6.8 (15.1) |
| | Sat | 2.5 (2.8) | 3.9 (8.8) | 9.0 (14.2) | 7.5 (14.6) |
| | Sun | 3.3 (8.9) | 6.3 (14.3) | 7.6 (15.2) | 4.0 (9.0) |
| Face mask | Yes | 4.1 (8.2) | 5.9 (14.8) | 7.7 (18.9) | 3.8 (4.7) |
| | No | 4.4 (11.6) | 5.5 (12.0) | 8.2 (16.6) | 5.5 (10.8) |
| Vaccinated | Yes | 4.1 (8.2) | 5.9 (14.8) | 7.7 (18.9) | 3.8 (4.7) |
| | No | 4.4 (11.6) | 5.5 (12.0) | 8.2 (16.6) | 5.5 (10.8) |
| High risk | Yes | 4.3 (11.2) | 4.1 (9.0) | 7.6 (17.1) | 4.9 (10.3) |
| | No | 4.4 (11.2) | 6.0 (12.9) | 8.5 (16.8) | 5.3 (9.9) |
| Employed (Adults) | Full time | 5.0 (12.8) | 6.7 (13.9) | 9.4 (17.7) | 5.6 (9.3) |
| | Part time | 6.8 (15.0) | 6.4 (12.3) | 9.8 (18.8) | 6.4 (12.5) |
| | Retired | 3.2 (7.4) | 3.4 (5.6) | 5.3 (11.4) | 3.7 (7.8) |
| | Self employed | 2.7 (3.9) | 21.6 (34.2) | 14.6 (28.1) | 4.4 (6.2) |
| | Unemployed | 3.3 (9.1) | 3.8 (8.4) | 5.4 (13.2) | 5.2 (12.8) |
| Work open (Adults) | | | | | |
| | closed | 3.1 (8.6) | 9.5 (24.7) | 8.4 (19.5) | 5.6 (8.2) |
| | open | 5.5 (13.2) | 7.6 (15.6) | 10.6 (19.8) | 6.1 (11.1) |
| Attended work (Adults) | | | | | |
| | no | 3.2 (5.2) | 4.7 (7.2) | 9.1 (17.8) | 4.4 (7.0) |
| | yes | 7.8 (17.5) | 9.3 (18.2) | 13.1 (22.7) | 7.0 (12.5) |

the pandemic, with several NPIs in place with a different extent, the level of contacts varied considerably between countries (e.g. from 2.64 to 7.25 average contacts per day) (Prem et al., 2017), with the exception of during lockdown measures, where contacts were more consistent between countries (Jarvis et al., 2020; Coletti et al., 2020; Latsuzbaia et al., 2020; Liu et al., 2021), and the main determinant of the number of contacts was the household size. The patterns of the frequency of contacts, whether they're physical or not, and the duration of contacts were somewhat similar to those seen prior to the pandemic.

We also observed that the proportion of individuals who think they are likely to get Covid was higher than those measured during the pandemic. In previous iterations of the CoMix survey (Prem et al., 2017), from March 2020 to March 2022, the average number of people who strongly agreed that they were likely to catch Coronavirus (perceived susceptibility) was 4.2 %, 4.2 % and 5.3 % for UK, Belgium and the Netherlands, to be compared with the higher proportion of 6.3 %, 7.4 % and 10.3 %. On the other hand, the percentage of participants who strongly agreed that coronavirus would lead them to serious illness (perceived severity) reduced from 14.3 %, 19.9 % and 25.5–8.5 %, 11.1 % and 13.4 % for UK, Belgium and the Netherlands respectively. A reduction was also observed for the perceived risk to the vulnerable, with the percentage of strong agreement decreasing from 19.4 %, 20.2 % and 26.3–15.6 % 7.7 % 13.2 % for UK, Belgium and the Netherlands, respectively. In conclusion, these results show that after the pandemic, COVID-19 infection is perceived as more probable, although causing fewer concerns in terms of personal risk and risk for the vulnerable. Given the relationship between perceived severity and contacts measured during the pandemic, this is one of the potential explanations for the increase in contacts that we observed (Wambua et al., 2023).

The CoMix study was nearly identical in the four countries, with the same questionnaire (apart from translation issues) and a similar sampling frame, and collected by the same survey organisation at the same calendar time. The study design was also the same as those used for the previous rounds of CoMix which allows for more straightforward comparison to the estimate calculated during the pandemic. We also structured our analyses to be consistent with previous analyses conducted for POLYMOD and CoMix.The need for consistency limited the amount of changes that could be implemented from one iteration of the CoMix survey to the next, requiring for example to account for the under-reporting due to participant fatigue and drop-out ex post (Loedy et al., 2023). Future longitudinal surveys should try to minimise participant fatigue by reducing the number of questions in the survey.

Our work presents some limitations that we discuss in what follows. A first difficulty of our study design is that it is retrospective (individuals were asked about their contacts on the previous day), so may miss contacts, particularly those that would be short lasting. Furthermore, the children's contacts are a proxy with parents reporting on behalf of those under 18. We also allow individuals to estimate mass contacts that they were unable to report individually, which results in skewed distributions of contacts and is why a maximum threshold value of 100 contacts per person is used for estimates of the mean, with results for a

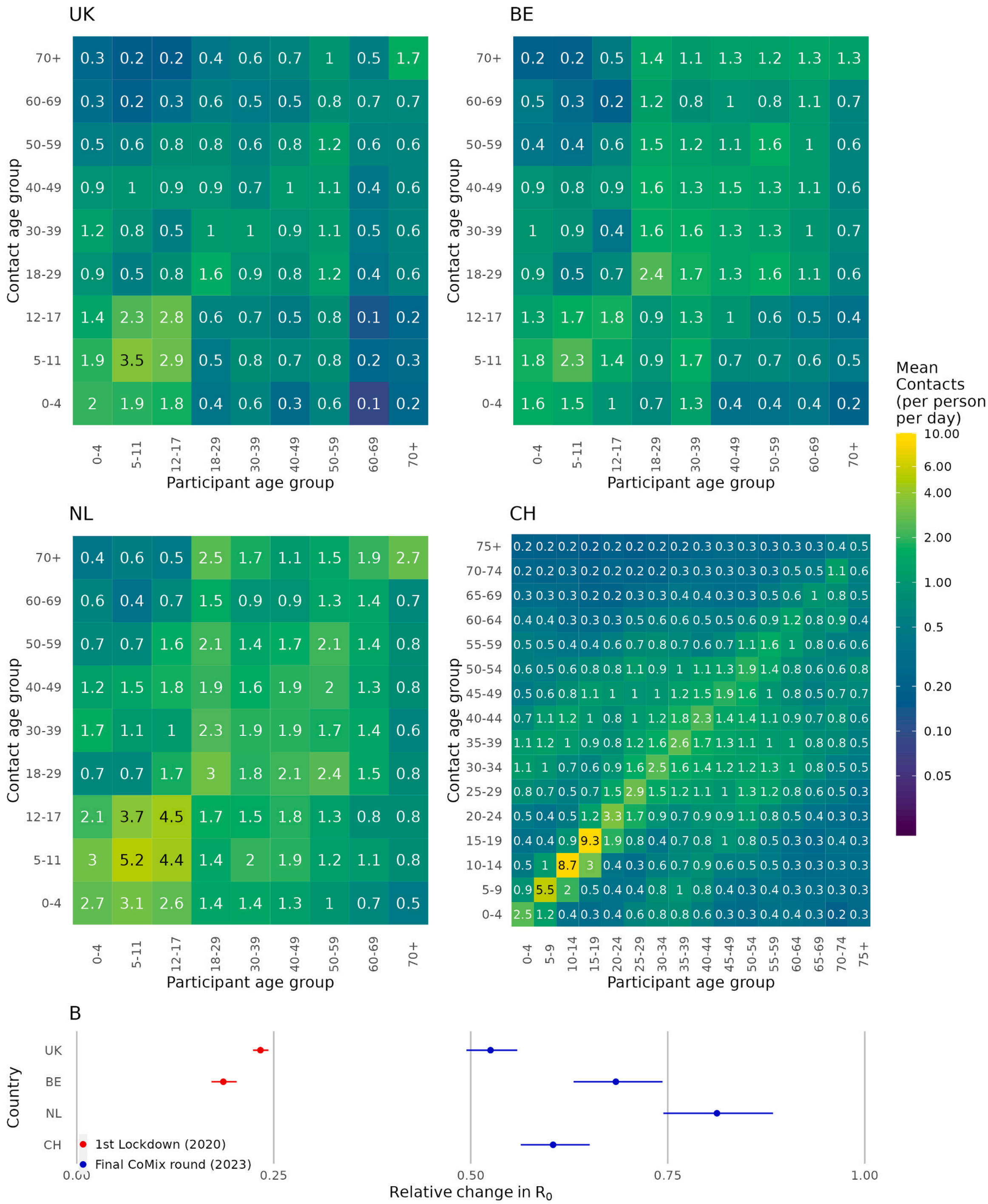


**Fig. 3.** A: Contact matrices for each country. B: Points show relative change in $R_0$ (compared to POLYMOD (Mossong et al., 2008) or Prem et al. (2017)) based on the dominant eigenvalues of contact matrices for the Final CoMix round (2023) in comparison with values measured during the 1st lockdown (2020) in UK (Jarvis et al., 2020) and Belgium (Coletti et al., 2020).

threshold value of 300 contacts per person showing however that results are quite robust. Finally, although the POLYMOD study and the CoMix study shared a similar questionnaire, other differences in implementation, such as using online surveys vs paper-based surveys, may hinder comparability. Furthermore, the POLYMOD study was performed more than ten years earlier than the COVID-19 pandemic. Therefore, potential changes in contact patterns between the study period of POLYMOD and the start of the pandemic may have not been taken into account, although a comparison with the POLYMOD study did not measure any significant change over a five year time span (Hoang et al., 2021).

This research provides a snapshot picture of contacts in four European nations during the return to post-pandemic patterns of behaviour. We have measurements that are higher than those seen during the pandemic but are still considerably lower than those measured in the POLYMOD study prior to the pandemic. It may be that the huge changes we saw during the pandemic are not over, and it will be important to monitor changes in contacts that may occur over the coming years.

It appears that the pandemic, at least in terms of behaviour, is ending very slowly and we are seeing a long return to contact level prior to 2019 as measured from the POLYMOD study, which has long been considered as the reference study for informing models of infectious diseases before and during the COVID-19 pandemic. Indeed, it could be that we may never return to the levels of contacts seen before the pandemic. The changes in work patterns, and behaviour that we experienced during the pandemic crisis may have resulted in long-lasting impacts with implications on the epidemiology of a wide range of infections, as well as on important societal and economic outcomes.

## 5. Conclusions

Despite the number of contacts being higher compared to pandemic levels, we are not back to the levels seen prior to the pandemic. The Netherlands and Belgium appear closer to pre-pandemic levels with the UK further behind. These divergences between countries may represent long-term changes and measuring the level of social interactions in the years to come will allow this to be assessed. Additionally, COVID-19 infection is perceived as more probable, although less severe and posing less of a threat to the vulnerable than during the pandemic.

Pandemics may not end with a bang but perhaps rather a slow and cautious trudge back to newly considered risky behaviour that was previously part of everyday life.

Declarations

## Ethics approval and consent to participate

Participation in this opt-in study was voluntary, and all analyses were carried out on anonymised data. The study was approved in the UK by the ethics committee of the London School of Hygiene & Tropical Medicine Reference number 21795. The study to collect CoMix data in Belgium was approved by the Ethics Committee of UZA with reference 3236 - BUN B3002020000054. The Medical Research Ethics Committee (MREC) NedMec confirmed that the Medical Research Involving Human Subjects Act (WMO) does not apply to the CoMix study in the Netherlands (research protocol number 22/917). Therefore an official approval of this study by the MREC NedMec is not required under the WMO. The study to collect CoMix data in Switzerland was approved by the ethics committee of the Canton of Bern (project number 2020–02926).

## Authors' contributions

WJE, and CIJ designed the CoMix contact survey. CIJ conceived of and planned the analysis. CIJ, PC, JAB, JDM, PB, NH, CLA, JW, CF, and WJE provided comments and discussions on analytical methods. CIJ, JDM, and PC conducted the analysis. CIJ wrote the first draft of the manuscript with feedback from all other authors.

## Consent for publication

Not applicable. We do not report individual patient data.

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## CRediT authorship contribution statement

**Jantien A Backer:** Writing – review & editing. **James D Munday:** Writing – review & editing. **Christel Faes:** Writing – review & editing. **Philippe Beutels:** Writing – review & editing. **Niel Hens:** Writing – review & editing. **W John Edmunds:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Christopher I Jarvis:** Writing – review & editing, Writing – original draft, Software, Project administration, Funding acquisition, Formal analysis. **Pietro Coletti:** Writing – review & editing, Methodology, Formal analysis. **Christian L Althaus:** Writing – review & editing. **Nicola Low:** Writing – review & editing. **Jacco Wallinga:** Writing – review & editing.

## Declaration of Competing Interest

None to declare.

## Data availability

The code and data used to conduct these analyses are found at https://github.com/jarvisc1/cmix_post_pandemic

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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.2024.100778.

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