Journal of Infection and Public Health 18 (2025) 102725

Contents lists available at ScienceDirect

Journal of Infection and Public Health

journal homepage: www.elsevier.com/locate/jiph

Original article

Quantifying social contact dynamics in South Korea in the post-COVID-19 endemic phase: A cross-sectional survey for infectious disease transmission

Gyeongseon Shin, SeungJin Bae *

College of Pharmacy, Ewha Womans University, Seoul 03760, South Korea

ARTICLE INFO

Article history:
Received 17 October 2024
Received in revised form 21 February 2025
Accepted 24 February 2025

Keywords:
Social contacts
Contacts matrix
Epidemiological model
Contact rates

ABSTRACT

Background: Understanding the dynamics of social contact patterns is crucial for modeling the spread of infectious diseases. Although previous studies have examined them globally, how relevant they are to social patterns in the endemic phase is still unclear. South Korea's distinct cultural norms, aging population, and declining fertility highlight the critical need for new, context-specific data. Here, we aim to conduct a contact survey in South Korea, providing age and location-specific contact estimates and quantifying patterns related to infectious disease transmission.

Methods: We conducted a cross-sectional survey in South Korea from July 6 to September 5, 2023. Participants of all ages were recruited using quota sampling based on the 2023 census, with only one individual per household included. Social contacts, both physical and non-physical, were recorded through a 24-hour diary. The data were analyzed with a negative binomial regression model. Age-specific contact matrices were constructed using census-based sampling weights, with uncertainty assessed through bootstrapping.

Results: A total of 1493 participants (740 males and 753 females) reported 14,187 contacts, with an average of 9.2 daily contacts (95 % confidence interval [CI]: 8.7–9.8). Contacts peaked at 17.8 (95 % CI: 14.6–21.5) among children aged 5–9 and were lowest at 3.5 (95 % CI: 2.6–4.5) for those aged 75 and above. Children and teenagers had a higher rate of peer-group contact, with most contacts occurring in workplaces or educational institutions. The level of family contact increased across all age groups.

Conclusion: We identified distinct social contact patterns in South Korea, such as high interactions within peer groups, which suggest the need for school-based vaccination programs, family-centered strategies, and workplace infection control measures. These findings provide critical baseline data to enhance disease modeling and inform professional public health policy development in South Korea and other cultural contexts.

© 2025 The Authors. Published by Elsevier Ltd on behalf of King Saud Bin Abdulaziz University for Health Sciences. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

As emerging infectious diseases—including respiratory pathogens like coronavirus disease 2019 (COVID-19) and influenza—continue challenging global health systems, understanding the human contact patterns driving their spread is more critical than ever [1]. These trends offer crucial information about the transmission pathways, the effectiveness of control measures, and strategies to combat diseases like COVID-19 [2,3]. For directly transmitted respiratory diseases, epidemiological models often rely on age-specific social mixing patterns, assuming that transmission rates align with social contact rates—a principle known as the "social contact hypothesis" [4,5]. This hypothesis posits that the age distribution of conversational contacts serves as a proxy for the spread of infectious respiratory agents, as both require spatial proximity.

Public health policies, such as closing schools, protecting vulnerable populations, and enforcing social distancing, heavily depend on understanding social contact patterns [6,7]. For instance, during the COVID-19 vaccination rollout in England, epidemiological models were used to project clinical demand, aiding the National Health Service in operational planning [8]. Similarly, South Korea

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019

* Corresponding author.
E-mail addresses: sunny628@ewha.ac.kr (G. Shin), sjbae@ewha.ac.kr (S. Bae).

https://doi.org/10.1016/j.jiph.2025.102725
1876-0341/© 2025 The Authors. Published by Elsevier Ltd on behalf of King Saud Bin Abdulaziz University for Health Sciences. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

adopted actions such as transitioning to online schooling and restrictions on community facilities [9]. These interventions demonstrate the critical role of real-time, context-specific data in informing effective public health strategies.

The POLYMOD study pioneered research on social contact rates through surveys across eight European countries, creating contact matrices that have become foundational for epidemiological modeling [1]. While subsequent studies have extended this research globally, most were conducted either before the pandemic [10–37] or during the pandemic [2,38–48], limiting their ability to account for fundamental behavioral shifts—such as remote work and altered social norms—that have emerged in the transition to the endemic phase.

In South Korea, the absence of context-specific data has often necessitated reliance on POLYMOD data, leading to uncertainties in public health policy modeling [49–52]. These uncertainties are compounded by South Korea's unique cultural context, including extended family caregiving, which influences transmission dynamics [53]. Furthermore, South Korea's rapidly declining fertility rate and aging population reshape social contact patterns, amplifying the need for updated data [54]. On a global scale, these demographic shifts, including rising life expectancy, demand that epidemiological models adapt to new social mixing paradigms [55].

This study aims to develop age-specific contact matrices that reflect South Korea's cultural norms and evolving demographic landscape. Using a POLYMOD-based survey across diverse age groups and social backgrounds, it characterizes the frequency, type, and location of daily interactions. These findings can inform tailored intervention strategies for the post-COVID-19 era and similar settings undergoing rapid demographic changes, ultimately enhancing epidemiological models for culturally diverse populations.

Methods

Survey design

This study was designed as a cross-sectional survey based on the POLYMOD study, foundational in epidemiological modeling [1]. The survey included a social contact diary and demographic information covering gender, age, occupation, and household size. "Social contact" was defined as (1) face-to-face, two-way communication involving at least three words within two meters without physical contact or (2) direct physical contact (e.g., handshake, hug, kiss, contact sports). Participants recorded all contacts from 00:00–23:59 on the specified day, noting details such as age, gender, location, duration, frequency, type (physical/non-physical), and mask status, which could reduce the risk of respiratory infections. Each participant received a printable diary form and uploaded their completed entries to an online platform (Appendix).

The survey was conducted online between July 6 and September 5, 2023, and participants, particularly students, were instructed not to respond during the vacation, thereby more accurately capturing their typical contact patterns during the school sessions. Proportionate quota sampling based on age, gender, and region was used to guarantee representativeness, aligned with 2023 South Korean census data [56]. Individuals aged 18–64 were recruited through survey agencies, while those aged 0–17 and 65 and above were directly recruited due to the requirement for written consent from a legal guardian. Guardians could complete the survey for participants who could not do so independently. Only one person per household was asked to participate in the survey. Instructions were provided to encourage truthful reporting and lessen information bias.

1493 of the original 1719 volunteers were analyzed. The survey was conducted in Korean and validated through a pilot test.

Age-specific contact pattern

We divided participants into 16 five-year age groups (0–4–75 +) and analyzed contact patterns using a negative binomial regression model adjusted for sampling weights to reflect census data. Age-specific contact rates were estimated using social contact matrices, including population size weights and reciprocal adjustments for consistency [45]. Further details on methodology, including matrix calculation and bootstrap sampling, are provided in the Supporting Information S1.

Comparative analysis of contact matrices

We compared our contact matrices with those from the POLYMOD study [1] and Prem *et al.* (2021) [57], which are widely used as substitutes for country-specific data. Using the data provided in these studies, we constructed contact matrices following the same methodology applied in our study to ensure consistency and comparability. These matrices were then visually compared to our empirical contact matrices. We calculated Pearson correlation coefficients and generated scatterplots to assess the agreement between datasets. We also examined the proportion of reported contacts by location (e.g., home, school or work, and other settings). We analyzed the proportion of physical contacts reported in our study and POLYMOD [1], as Prem *et al.* (2021) [57] does not include physical contact data.

Statistical analysis

All statistical analyses, including negative binomial regression, Pearson correlation, and data visualization (scatterplots, contact matrices), were performed using R version 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria). Analysis scripts and survey data are accessible on GitHub (https://github.com/KRcontact/2024).

Ethics statement

The study was approved by the Institutional Review Board of Ewha Womans University (IRB ewha-202306–0003–02). Before participation, all subjects or their legal guardians provided informed consent after being informed about the purpose of the study and how their data would be used. Relevant guidelines and regulations conducted all procedures, and the study adhered to national ethical standards to ensure participant anonymity.

Results

Study population

To recruit participants for the survey, 1719 individuals initially consented via email and online postings. However, 59 did not confirm participation in the final survey, and 167 discontinued participation, resulting in 1493 participants in the final analysis. There was no difference in gender distribution between our sample and the 2023 South Korea Census data (p = 0.65), but age distribution differed (p = 0.02), particularly in the 75 + age group (Fig. S1 **and** Table S1).

Number of contacts

A total of 14,187 contacts were reported by 740 male and 753 female respondents. Five respondents reported no contacts and were included in the overall analysis. The mean number of daily contacts per person, adjusted for sampling weights, was 9.2 (95 % confidence interval [CI] 8.7–9.8), with 51.8 % of respondents reporting five or fewer contacts per day. The top 5 % of respondents accounted for

Table 1
Relative frequency of all contacts and physical contacts by different characteristics of the participants.

		N (%)	Relative degree of all contacts (95 % CI)	Relative degree of physical contacts (95 % CI)
Overall		1493 (100.0)		
Gender				
	Male	740 (49.6)	REF	REF
	Female	753 (50.4)	0.83 (0.76–0.91)***	0.88 (0.81–0.96)**
Age group				
	0–4	42 (2.8)	REF	REF
	5–9	59 (4.0)	2.17 (1.53–3.07)***	1.88 (1.39–2.55)***
	14–10	78 (5.2)	2.05 (1.47–2.86)***	1.24 (0.93–1.67)
	15–19	74 (5.0)	1.82 (1.30–2.55)***	1.00 (0.74–1.35)
	20–24	82 (5.5)	1.87 (1.34–2.61)***	0.76 (0.56–1.02)
	25–29	98 (6.6)	1.58 (1.14–2.19)**	0.68 (0.51–0.92)*
	30–34	106 (7.1)	1.19 (0.86–1.65)***	0.46 (0.34–0.62)***
	35–39	95 (6.4)	1.15 (0.83–1.60)	0.48 (0.35–0.64)***
	40–44	125 (8.4)	1.19 (0.87–1.63)	0.54 (0.40–0.71)***
	45–49	120 (8.0)	1.35 (0.98–1.85)	0.49 (0.36–0.65)***
	50–54	139 (9.3)	1.21 (0.89–1.66)	0.54 (0.41–0.71)***
	55–59	122 (8.2)	1.12 (0.82–1.54)	0.40 (0.30–0.53)***
	60–64	124 (8.3)	1.29 (0.94–1.77)	0.52 (0.39–0.69)***
	65–69	97 (6.5)	0.65 (0.46–0.92)*	0.32 (0.23–0.44)***
	70–74	68 (4.6)	0.72 (0.50–1.04)	0.33 (0.23–0.47)***
	75 +	64 (4.3)	0.60 (0.41–0.87)**	0.31 (0.22–0.45)***
Household size				
	1	168 (11.3)	REF	REF
	2	340 (22.8)	0.76 (0.63–0.90)**	0.79 (0.66–0.94)*
	3	477 (31.9)	0.87 (0.74–1.03)	0.99 (0.83–1.17)
	4	384 (25.7)	0.98 (0.82–1.16)	1.37 (1.15–1.63)***
	5 +	124 (8.3)	1.08 (0.87–1.34)	1.39 (1.13–1.73)**
Household income[a]				
	Low	347 (23.2)	REF	REF
	Middle	883 (59.1)	1.22 (1.08–1.38)**	1.19 (1.05–1.35)**
	High	263 (17.6)	1.39 (1.19–1.62)***	1.37 (1.17–1.59)***
Day of week				
	Weekday	1170 (78.4)	REF	REF
	Weekend	323 (21.6)	0.69 (0.62–0.78)***	0.93 (0.83–1.04)

CI = confidence interval
[a] Household income was defined as follows: less than $2200 per month as low, $2200 to $5800 per month as middle, and more than $5800 per month as high.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

25.4 % of all contacts, primarily students and employed individuals with inherently higher contact rates (Fig. S2).

The average daily contacts varied by age, peaking at 17.8 (95 % CI 14.6–21.5) for ages 5–9 and lowest at 3.5 (95 % CI 2.6–4.5) for those 75 and above (Table S2). Participants from high-income households reported a significant increase in physical and all contacts ($p < 0.001$). Weekend contacts showed a significant decrease in total contacts ($p < 0.001$), while no significant difference was observed in physical contacts (Table 1).

We used a negative binomial multivariate regression model to assess the relative frequency of all contacts and physical contacts based on gender, age, household size, income, and day of the week (Table 1). City and profession were included in the initial model but were excluded as they did not demonstrate statistically significant effects on contact patterns.

Overall, males reported slightly higher contact rates than females across most age groups, with overlapping confidence intervals suggesting no significant differences. A notable exception was the 35–39 age group, where males reported significantly higher contacts compared to females ($p < 0.001$) (Fig. S3, Table S3).

Duration, frequency, and location of contacts

Most reported contacts occurred in educational institutions or workplaces (Fig. S4). Younger age groups, particularly children and adolescents, reported more frequent and prolonged contacts, primarily within educational institutions, while older individuals (65 and above) had a higher proportion of leisure-based contacts. Most contacts lasted over an hour at home, followed by workplaces and educational institutions, accounting for the highest frequency of daily interactions. Short contacts were more common with new acquaintances (Fig. 1). Physical contact was a key indicator of contact intensity, particularly in caregiving or household routines, where prolonged and frequent interactions often involved physical contact (Fig. 1, Fig. S5).

Comparison of weekday and weekend contacts

21.6 % (323/1493) of respondents reported weekend contact, showing significant differences in contact patterns between weekdays and weekends. Overall, contacts were higher on weekdays, driven by interactions in educational institutions, particularly for children and adolescents (Fig. S6A). On weekends, contacts for these groups declined markedly due to reduced school-related activities (Fig. S6B, **C**).

In contrast, individuals aged 25–59 and those 60 and over reported similar or higher contact levels on weekends than on weekdays. This increase was primarily attributed to leisure activities, including dining out, attending social gatherings, and outdoor activities like hiking or visiting parks (Fig. S6B, **C**).

Social Contact Patterns

Participants reported more interactions with individuals of similar ages, especially among school-aged children, with those aged 5–9 showing a strong pattern due to kindergarten or early

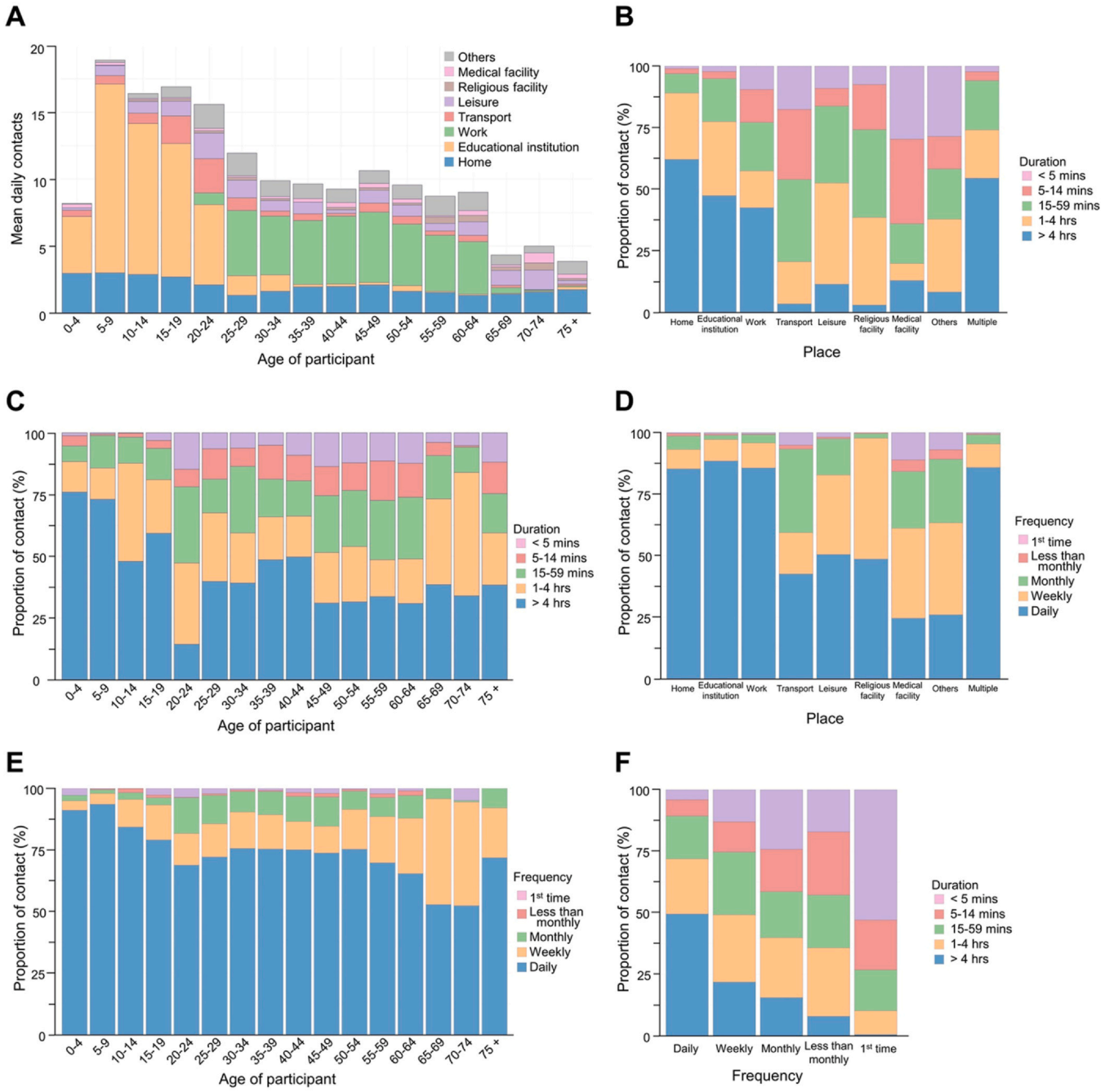


Fig. 1. Distribution of contact patterns. (A) Mean daily contacts by age and location; (B) proportion of contacts by locations and duration; (C) proportion of contacts by age and duration; (D) proportion of contacts by frequency and locations; (E) proportion of contacts by age and frequency; (F) proportion of contacts by frequency and duration.

primary school contacts. This group's expected number of symmetrized contacts was 14.19, assuming random mixing. Across all ages, increased contact intensity was noted within family contacts, seen as two parallel secondary diagonals starting at age 30–35 (Fig. 2, Fig. S7). For those aged 25–64, a high contact intensity plateau was observed, driven by frequent workplace and social contacts, reflecting their active economic and social roles. Among children aged 0–4, the difference between total and physical contact was the smallest across all age groups. In contrast, among those aged 15 and older, physical contacts accounted for less than half of the total contacts (Fig. 2). The symmetrized contact matrices are shown in Fig. 2. In contrast, the raw contact matrices are displayed in Fig. S8. Detailed numerical data are provided in Table S4.

Comparison with the synthetic matrix and POLYMOD

We compared the contact matrices derived from our empirical contact survey with those from the synthetic matrix reported by Prem *et al.* (2021) [57] and POLYMOD [1], observing high correlations of 0.87 and 0.92, respectively (Fig. 3**A, B**). Overall, the number of daily contacts was lower in the empirical contact survey than in the synthetic matrix and POLYMOD. However, among individuals under 30, our survey showed higher peer-group contact rates, leading to notable differences from the synthetic matrix and POLYMOD (Fig. 3**C, D**). A closer comparison of our data with POLYMOD revealed higher average contact rates and physical contact proportions in POLYMOD, except for Korean children aged 5–9, who exhibited more frequent contact than reported in POLYMOD

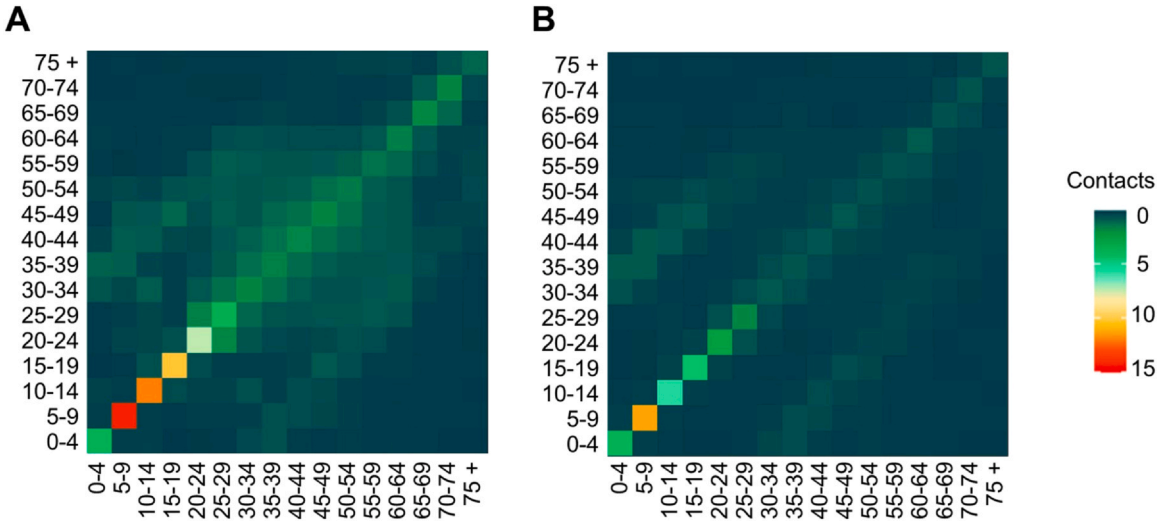


Fig. 2. Age-structured contact matrices in South Korea. (A) Symmetrized matrix of all reported contacts; (B) symmetrized matrix of reported physical contacts.

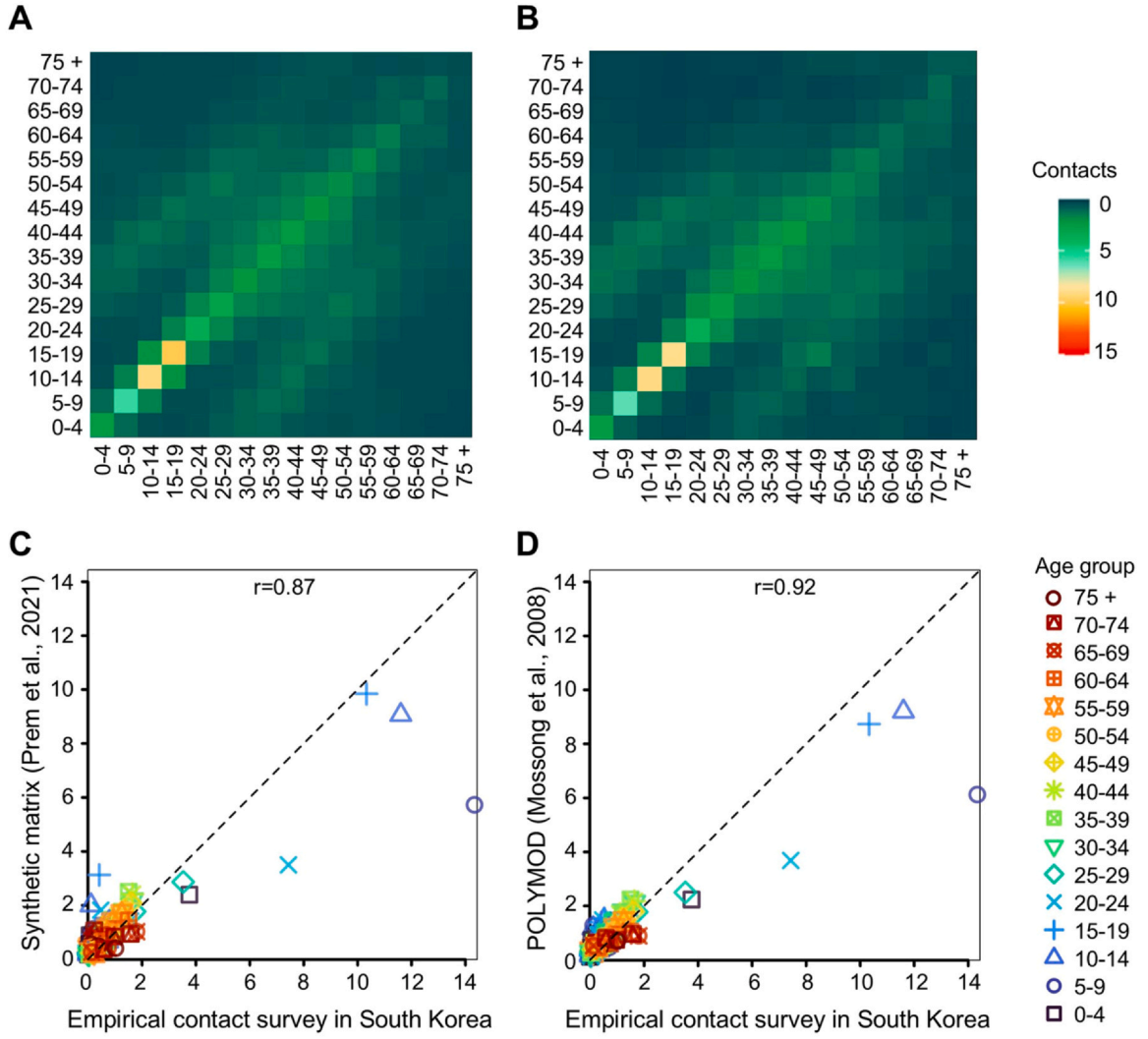


Fig. 3. Comparison of age-specific contact matrices and correlation analyses across datasets. (A) The South Korea contact synthetic matrix reported by Prem *et al.* (2021); (B) contact matrix from POLYMOD (Mossong *et al.* 2008); (C) correlation between empirical contact survey data from South Korea and the synthetic matrix reported by Prem *et al.* (2021); (D) correlation between empirical contact survey data from South Korea and POLYMOD data.

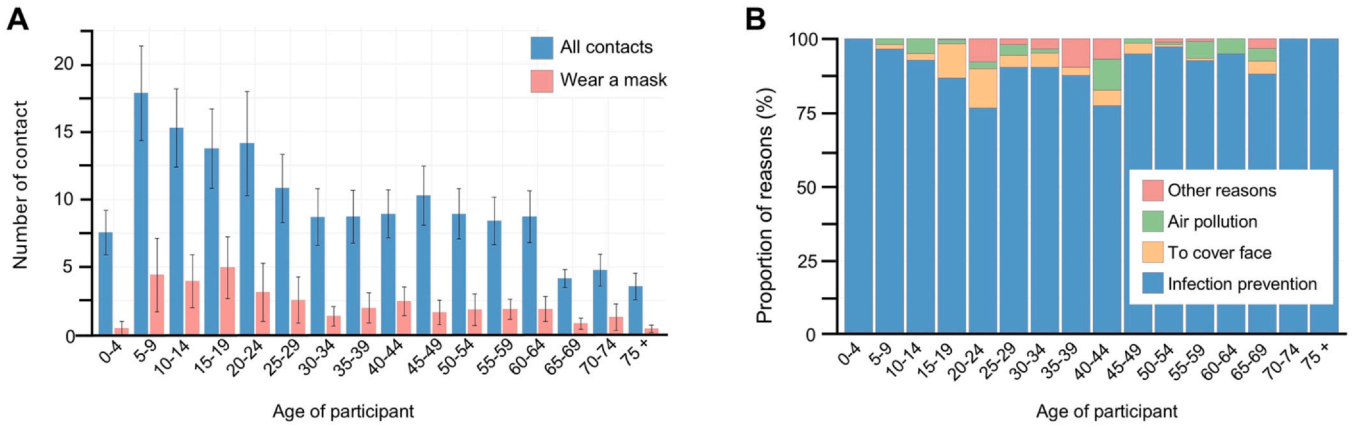


Fig. 4. Analysis of mask-wearing contacts across different age groups. (A) Comparison of total contacts and mask-wearing contacts; (B) distribution of reasons for wearing a mask.

(Fig. S9). Regarding contact locations, the contact patterns at home were relatively similar between our survey and those reported in POLYMOD. However, our empirical data showed a higher proportion of daily contact occurring at educational institutions or workplaces, particularly among individuals under 20. Conversely, the proportion of daily contacts at other locations—transport, leisure, religious facilities, medical facilities, and other locations—was generally lower in our survey than POLYMOD (Fig. S10).

Mask wearing

While mask-wearing was not mandated, masks were worn during 16.4 % of contacts (95 % CI 14.8–18.1 %). This proportion was higher among teenagers and young adults in their early twenties and lower among very young children aged 0–4 years and elderly individuals aged 75 and above (Fig. 4**A**). The predominant reason cited for mask-wearing was infection prevention (90.1 %; 95 % CI 89.0–91.1 %). Cultural factors, such as the widespread acceptance of mask-wearing during the pandemic, likely influenced this behavior, even without government requirements (Fig. 4**B**).

Discussion

To the best of our knowledge, this study is among the first to investigate social contact patterns following COVID-19's transition to an endemic phase, capturing post-pandemic behavioral changes. Conducted after the World Health Organization declared the end of the Public Health Emergency of International Concern, this study focuses on South Korea, where sociocultural factors like a low birth rate and emphasis on education significantly shape contact dynamics. Using methodologies similar to the POLYMOD study, we quantified contact patterns across age groups, providing foundational data for improving infectious disease modeling and informing targeted interventions, such as school-based vaccination campaigns and age-specific prevention strategies.

In our study, the mean number of contacts reported was 9.2 (95 % CI 8.7–9.8), including an average of 4.0 physical contacts (95 % CI 3.7–4.2). These figures are somewhat lower than the average of 13.4 contacts reported in the POLYMOD study and below the contact rates observed in most European countries, except Germany [1]. Compared to East Asian countries, our findings are generally lower than those in Japan (15.3) [18], China (18.6–18.7) [2,19], and Hong Kong (8.1–18.0) [4,29,30]. Prolonged non-pharmaceutical interventions, such as mandatory mask-wearing and social distancing in South Korea, likely heightened the perceived severity of COVID-19 and contributed to reduced contact rates [38,46]. Alternatively, the observed differences could result from the complexity of social contact survey methodologies across studies (Table S5). Given these methodological disparities, focusing on age-specific contact patterns—such as identifying which groups have relatively higher and more sustained interactions—rather than directly comparing contact rates may provide more meaningful insights for future research.

Our study observed several distinctive patterns in social contact dynamics. One notable feature was the higher proportion of daily contacts occurring within educational institutions or workplaces compared to the POLYMOD study, as well as higher peer-group contact rates, particularly among children and adolescents. Compared to European countries, South Korea is known for having longer workdays and school days [58,59], which probably leads to more interpersonal interactions and the observed differences in contact patterns. Meanwhile, high peer-group contact highlight the unique demographic context of South Korea. With a fertility rate of 0.72 in 2023—two to three times lower than that of European countries—South Korea has seen a decline in sibling interactions and an increase in peer-group interactions among younger age groups [60]. This concentrated social structure sustains high transmission potential within peer groups, emphasizing the need for targeted public health measures such as school-based vaccination programs and age-specific infection prevention strategies. Expanding vaccination efforts to include adolescents with high social contact rates could significantly reduce disease transmission. Evidence from Germany supports this approach, showing that adolescent vaccination notably decreased the incidence and mortality of invasive meningococcal disease across all age groups [61]. For adults aged 25–64, a high contact intensity plateau was observed, primarily attributed to frequent workplace and social interactions. This finding highlights the need for workplace-focused public health initiatives, such as enhanced ventilation, infection control measures, and workplace vaccination programs, to reduce the risks of disease transmission within this active population [62].

Additionally, there was an increase in the intensity of family contact across all age groups. Notably, overall social contacts significantly decreased among women aged 35–39, while contacts with young children within the family were higher. This trend is consistent with the remarkably low percentage of South Korean women who remain employed after having children [63], leading to reduced workplace and external social interactions. The findings emphasize the importance of families in the spread of disease and the necessity of family-centered vaccinations and support.

Our study has several limitations. First, for participants with young children and elderly individuals, recruitment was conducted separately to obtain legal guardian consent. Additionally, proxy responses were used when direct reporting was not feasible, which may have introduced reporting bias. To mitigate this, we ensured a proportional representation of these groups based on the 2023 census and employed symmetric contact matrices to reduce data

variability. Second, the retrospective design may have introduced recall bias, leading to underreporting of contacts. However, these problems were mitigated by the short recall period and the provision of printable diaries, along with participant instructions to record contacts as soon as possible [64]. Third, selection bias may have occurred due to voluntary participation, potentially underrepresenting individuals less familiar with online environments or overrepresenting those with higher social activity levels. Fourth, we instructed participants not to respond during school holidays to capture typical contact patterns. However, since school-aged children primarily interact in school settings, their contact patterns may differ significantly during vacations [65]. It may be related to the higher contact rates observed in our study compared to previous studies reporting school-aged children's contact patterns. These potential biases warrant further investigation in future studies.

In conclusion, this study is the first to quantify social contact patterns after COVID-19 became endemic, offering essential baseline data that improves our comprehension of infectious disease transmission and shapes helpful public health strategies. While our findings provide valuable insights, they should be interpreted cautiously due to limitations, such as potential biases from self-reported data and the exclusion of holiday periods for school-aged participants. Despite these limitations, the findings can guide South Korea in improving pandemic preparedness, tailoring vaccination campaigns to specific age groups, and optimizing social distancing measures based on observed contact patterns. Globally, this study offers a framework for similar research and policy development in countries with comparable demographic and cultural contexts, contributing to better management of future outbreaks.

Ethical approval

The study was approved by the Institutional Review Board of Ewha Womans University in Seoul, South Korea (IRB ewha-202306–0003–02).

Funding statement

This work was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education [2022R1A6A3A01087214].

CRediT authorship contribution statement

GS, and SB conceptualized the study. The data included in this article were retrieved by GS. GS carried out the data analysis. GS contributed to the visualization of the data. SB provided critical feedback on methods, results, discussion and revision. GS, SB contributed to interpretation of data for the work. SB contributed to managing the overall research enterprise. GS had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. GS and SB were involved in writing the original draft and revising the article critically for important intellectual content. SB approved the final version of the manuscript. GS and SB directly accessed and verified the underlying data. All authors are accountable for all aspects of the work.

Data availability

Social contact matrices are included in the Supplementary Materials and the scripts used for data analysis are openly accessible via our GitHub repository, available at http://github.com/KRcontact/2024.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT-4o in order to improve language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jiph.2025.102725.

References

[1] Mossong J, Hens N, Jit M, Beutels P, Auranen K, Mikolajczyk R, et al. Social contacts and mixing patterns relevant to the spread of infectious diseases. PLoS Med 2008;5(3):e74. https://doi.org/10.1371/journal.pmed.0050074
[2] Zhang J, Litvinova M, Liang Y, Wang Y, Wang W, Zhao S, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. Sci 2020;368(6498):1481–6. https://doi.org/10.1126/science.abb8001
[3] Yuan H-Y, Liang J, Hossain MP. Impacts of social distancing, rapid antigen test and vaccination on the Omicron outbreak during large temperature variations in Hong Kong: a modelling study. J Infect Public Health 2022;15(12):1427–35. https://doi.org/10.1016/j.jiph.2022.10.026
[4] Leung WTM, Meeyai A, Holt HR, Khieu B, Chhay T, Seng S, et al. Social contact patterns relevant for infectious disease transmission in Cambodia. Sci Rep 2023;13(1):5542. https://doi.org/10.1038/s41598-023-31485-z
[5] Wallinga J, Teunis P, Kretzschmar M. Using data on social contacts to estimate age-specific transmission parameters for respiratory-spread infectious agents. Am J Epidemiol 2006;164(10):936–44. https://doi.org/10.1093/aje/kwj317
[6] Ferguson NM, Laydon D, Nedjati-Gilani G, Imai N, Ainslie K, Baguelin M, et al. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Imp Coll Lond 2020;16(3):1–20. https://doi.org/10.25561/77482
[7] Ryu S, Han C, Ali ST, Achangwa C, Yang B, Pei S. Association of public health and social measures on the hand-foot-mouth epidemic in South Korea. J Infect Public Health 2023;16(6):859–64. https://doi.org/10.1016/j.jiph.2023.03.029
[8] Groves-Kirkby N, Wakeman E, Patel S, Hinch R, Poot T, Pearson J, et al. Large-scale calibration and simulation of COVID-19 epidemiologic scenarios to support healthcare planning. Epidemics 2023;42:100662. https://doi.org/10.1016/j.epidem.2022.100662
[9] Jeong E, Hagose M, Jung H, Ki M, Flahault A. Understanding South Korea's response to the COVID-19 outbreak: a real-time analysis. Int J Env Res Public Health 2020;17(24):9571. https://doi.org/10.3390/ijerph17249571
[10] Béraud G, Kazmercziak S, Beutels P, Levy-Bruhl D, Lenne X, Mielcarek N, et al. The French connection: the first large population-based contact survey in France relevant for the spread of infectious diseases. PLoS One 2015;10(7):e0133203. https://doi.org/10.1371/journal.pone.0133203
[11] Danon L, House TA, Read JM, Keeling MJ. Social encounter networks: collective properties and disease transmission. J R Soc Interface 2012;9(76):2826–33. https://doi.org/10.1098/rsif.2012.0357
[12] Dodd PJ, Looker C, Plumb ID, Bond V, Schaap A, Shanaube K, et al. Age-and sex-specific social contact patterns and incidence of Mycobacterium tuberculosis infection. Am J Epidemiol 2016;183(2):156–66. https://doi.org/10.1093/aje/kwv160
[13] Kifle YW, Goeyvaerts N, Van Kerckhove K, Willem L, Faes C, Leirs H, et al. Animal ownership and touching enrich the context of social contacts relevant to the spread of human infectious diseases. PLoS One 2015;10(7):e0133461. https://doi.org/10.1371/journal.pone.0133461
[14] Melegaro A, Del Fava E, Poletti P, Merler S, Nyamukapa C, Williams J, et al. Social contact structures and time use patterns in the Manicaland Province of Zimbabwe. PLoS One 2017;12(1):e0170459. https://doi.org/10.1371/journal.pone.0170459
[15] Neal EF, Flasche S, Nguyen CD, Ratu FT, Dunne EM, Koyamaibole L, et al. Associations between ethnicity, social contact, and pneumococcal carriage three years post-PCV10 in Fiji. Vaccine 2020;38(2):202–11. https://doi.org/10.1016/j.vaccine.2019.10.030
[16] Rolls DA, Geard NL, Warr DJ, Nathan PM, Robins GL, Pattison PE, et al. Social encounter profiles of greater Melbourne residents, by location–a telephone survey. BMC Infect Dis 2015;15:1–11. https://doi.org/10.1186/s12879-015-1237-9
[17] van Zandvoort K, Bobe MO, Hassan AI, Abdi MI, Ahmed MS, Soleman SM, et al. Social contacts and other risk factors for respiratory infections among internally displaced people in Somaliland. Epidemics 2022;41:100625. https://doi.org/10.1016/j.epidem.2022.100625

[18] Ibuka Y, Ohkusa Y, Sugawara T, Chapman GB, Yamin D, Atkins KE, et al. Social contacts, vaccination decisions and influenza in Japan. J Epidemiol Community Health 2016;70(2):162–7. https://doi.org/10.1136/jech-2015-205777
[19] Read JM, Lessler J, Riley S, Wang S, Tan LJ, Kwok KO, et al. Social mixing patterns in rural and urban areas of southern China. Proc R Soc B 2014;281(1785):20140268. https://doi.org/10.1098/rspb.2014.0268
[20] Horby P, Thai PQ, Hens N, Yen NTT, Mai LQ, Thoang DD, et al. Social contact patterns in Vietnam and implications for the control of infectious diseases. PLoS One 2011;6(2):e16965. https://doi.org/10.1371/journal.pone.0016965
[21] Ajelli M, Litvinova M. Estimating contact patterns relevant to the spread of infectious diseases in Russia. J Theor Biol 2017;419:1–7. https://doi.org/10.1016/j.jtbi.2017.01.041
[22] Beutels P, Shkedy Z, Aerts M, Van Damme P. Social mixing patterns for transmission models of close contact infections: exploring self-evaluation and diary-based data collection through a web-based interface. Epidemiol Infect 2006;134(6):1158–66. https://doi.org/10.1017/S0950268806006418
[23] Fu Y-c, Wang D-W, Chuang J-H. Representative contact diaries for modeling the spread of infectious diseases in Taiwan. PLoS One 2012;7(10):e45113. https://doi.org/10.1371/journal.pone.0045113
[24] Grijalva CG, Goeyvaerts N, Verastegui H, Edwards KM, Gil AI, Lanata CF, et al. A household-based study of contact networks relevant for the spread of infectious diseases in the highlands of Peru. PLoS One 2015;10(3):e0118457. https://doi.org/10.1371/journal.pone.0118457
[25] Johnstone-Robertson SP, Mark D, Morrow C, Middelkoop K, Chiswell M, Aquino LD, et al. Social mixing patterns within a South African township community: implications for respiratory disease transmission and control. Am J Epidemiol 2011;174(11):1246–55. https://doi.org/10.1093/aje/kwr251
[26] Kiti MC, Kinyanjui TM, Koech DC, Munywoki PK, Medley GF, Nokes DJ. Quantifying age-related rates of social contact using diaries in a rural coastal population of Kenya. PLoS One 2014;9(8):e104786. https://doi.org/10.1371/journal.pone.0104786
[27] Kucharski AJ, Kwok KO, Wei VW, Cowling BJ, Read JM, Lessler J, et al. The contribution of social behaviour to the transmission of influenza A in a human population. PLoS Pathog 2014;10(6):e1004206. https://doi.org/10.1371/journal.ppat.1004206
[28] Kumar S, Gosain M, Sharma H, Swetts E, Amarchand R, Kumar R, et al. Who interacts with whom? Social mixing insights from a rural population in India. PLoS One 2018;13(12):e0209039. https://doi.org/10.1371/journal.pone.0209039
[29] Kwok KO, Cowling B, Wei V, Riley S, Read JM. Temporal variation of human encounters and the number of locations in which they occur: a longitudinal study of Hong Kong residents. J R Soc Interface 2018;15(138):20170838. https://doi.org/10.1098/rsif.2017.0838
[30] Kwok KO, Cowling BJ, Wei VW, Wu KM, Read JM, Lessler J, et al. Social contacts and the locations in which they occur as risk factors for influenza infection. Proc R Soc B 2014;281(1789):20140709. https://doi.org/10.1098/rspb.2014.0709
[31] Le Polain de Waroux O, Cohuet S, Ndazima D, Kucharski A, Juan-Giner A, Flasche S, et al. Characteristics of human encounters and social mixing patterns relevant to infectious diseases spread by close contact: a survey in Southwest Uganda. BMC Infect Dis 2018;18:1–12. https://doi.org/10.1186/s12879-018-3073-1
[32] Leung K, Jit M, Lau EH, Wu JT. Social contact patterns relevant to the spread of respiratory infectious diseases in Hong Kong. Sci Rep 2017;7(1):7974. https://doi.org/10.1038/s41598-017-08241-1
[33] Mahikul W, Kripattanapong S, Hanvoravongchai P, Meeyai A, Iamsirithaworn S, Auewarakul P, et al. Contact mixing patterns and population movement among migrant workers in an urban setting in Thailand. Int J Env Res Public Health 2020;17(7):2237. https://doi.org/10.3390/ijerph17072237
[34] McCaw JM, Forbes K, Nathan PM, Pattison PE, Robins GL, Nolan TM, et al. Comparison of three methods for ascertainment of contact information relevant to respiratory pathogen transmission in encounter networks. BMC Infect Dis 2010;10:1–11. https://doi.org/10.1186/1471-2334-10-166
[35] Munasinghe L, Asai Y, Nishiura H. Quantifying heterogeneous contact patterns in Japan: A social contact survey. Theor Biol Med Model 2019;16:1–10. https://doi.org/10.1186/s12976-019-0102-8
[36] Stein ML, Van Steenbergen JE, Buskens V, Van Der Heijden PG, Chanyasanha C, Tipayamongkholgul M, et al. Comparison of contact patterns relevant for transmission of respiratory pathogens in Thailand and the Netherlands using respondent-driven sampling. PLoS One 2014;9(11):e113711. https://doi.org/10.1371/journal.pone.0113711
[37] Wood R, Racow K, Bekker L-G, Morrow C, Middelkoop K, Mark D, et al. Indoor social networks in a South African township: potential contribution of location to tuberculosis transmission. PLoS One 2012;7(6):e39246. https://doi.org/10.1371/journal.pone.0039246
[38] Jarvis CI, Coletti P, Backer JA, Munday JD, Faes C, Beutels P, et al. Social contact patterns following the COVID-19 pandemic: a snapshot of post-pandemic behaviour from the CoMix study. Epidemics 2024;48:100778. https://doi.org/10.1016/j.epidem.2024.100778
[39] Backer JA, Van de Kassteele J, El Fakiri F, Hens N, Wallinga J. Contact patterns of older adults with and without frailty in the Netherlands during the COVID-19 pandemic. BMC Public Health 2023;23(1):1829. https://doi.org/10.1186/s12889-023-16725-1
[40] Veneti L, Robberstad B, Steens A, Forland F, Winje BA, Vestrheim DF, et al. Social contact patterns during the early COVID-19 pandemic in Norway: insights from a panel study, April to September 2020. BMC Public Health 2024;24(1):1438. https://doi.org/10.1186/s12889-024-18853-8
[41] Tizzani M, De Gaetano A, Jarvis CI, Gimma A, Wong K, Edmunds WJ, et al. Impact of tiered measures on social contact and mixing patterns of in Italy during the second wave of COVID-19. BMC Public Health 2023;23(1):906. https://doi.org/10.1186/s12889-023-15846-x
[42] Backer JA, Bogaardt L, Beutels P, Coletti P, Edmunds WJ, Gimma A, et al. Dynamics of non-household contacts during the COVID-19 pandemic in 2020 and 2021 in the Netherlands. Sci Rep 2023;13(1):5166. https://doi.org/10.1038/s41598-023-32031-7
[43] Coletti P, Wambua J, Gimma A, Willem L, Vercruysse S, Vanhoutte B, et al. CoMix: comparing mixing patterns in the Belgian population during and after lockdown. Sci Rep 2020;10(1):21885. https://doi.org/10.1038/s41598-020-78540-7
[44] Nelson KN, Siegler AJ, Sullivan PS, Bradley H, Hall E, Luisi N, et al. Nationally representative social contact patterns among US adults, August 2020-April 2021. Epidemics 2022;40:100605. https://doi.org/10.1016/j.epidem.2022.100605
[45] Feehan DM, Mahmud AS. Quantifying population contact patterns in the United States during the COVID-19 pandemic. Nat Commun 2021;12(1):893. https://doi.org/10.1038/s41467-021-20990-2
[46] Wambua J, Loedy N, Jarvis CI, Wong KL, Faes C, Grah R, et al. The influence of COVID-19 risk perception and vaccination status on the number of social contacts across Europe: insights from the CoMix study. BMC Public Health 2023;23(1):1350. https://doi.org/10.1186/s12889-023-16252-z
[47] Gimma A, Munday JD, Wong KL, Coletti P, van Zandvoort K, Prem K, et al. Changes in social contacts in England during the COVID-19 pandemic between March 2020 and March 2021 as measured by the CoMix survey: A repeated cross-sectional study. PLoS Med 2022;19(3):e1003907. https://doi.org/10.1371/journal.pmed.1003907
[48] Latsuzbaia A, Herold M, Bertemes J-P, Mossong J. Evolving social contact patterns during the COVID-19 crisis in Luxembourg. PLoS One 2020;15(8):e0237128. https://doi.org/10.1371/journal.pone.0237128
[49] Lee T, Suh J, Choi J-K, Lee J, Park SH. Estimating the basic reproductive number of varicella in South Korea incorporating social contact patterns and seroprevalence. Hum Vaccin Immunother 2021;17(8):2488–93. https://doi.org/10.1080/21645515.2021.1898917
[50] Lee Y, Lee DH, Kwon H-D, Kim C, Lee J. Estimation of the reproduction number of influenza A (H1N1) pdm09 in South Korea using heterogeneous models. BMC Infect Dis 2021;21:1–11. https://doi.org/10.1186/s12879-021-06121-8
[51] Suh J, Choi J-K, Lee J, Park SH. Estimation of single-dose varicella vaccine effectiveness in South Korea using mathematical modeling. Hum Vaccin Immunother 2022;18(5):2085468. https://doi.org/10.1080/21645515.2022.2085468
[52] Suh J, Lee T, Choi J-K, Lee J, Park SH. The impact of two-dose varicella vaccination on varicella and herpes zoster incidence in South Korea using a mathematical model with changing population demographics. Vaccine 2021;39(18):2575–83. https://doi.org/10.1016/j.vaccine.2021.03.056
[53] Chung S, Park A. The longitudinal effects of grandchild care on depressive symptoms and physical health of grandmothers in South Korea: a latent growth approach. Aging Ment Health 2018;22(12):1556–63. https://doi.org/10.1080/13607863.2017.1376312
[54] Mehri N, Messkoub M, Kunkel S. Trends, determinants and the implications of population aging in Iran. Ageing Int 2020;45(4):327–43. https://doi.org/10.1007/s12126-020-09364-z
[55] Ince Yenilmez M. Economic and social consequences of population aging the dilemmas and opportunities in the twenty-first century. Appl Res Qual Life 2015;10:735–52. https://doi.org/10.1007/s11482-014-9334-2
[56] Statistics Korea. Population statistics in South Korea. Statistics Korea, ⟨https://kosis.kr/statHtml/statHtml.do?orgId= 101&tblId=DT_1B04006&conn_path=I3⟩. [accessed 24 December 2024].
[57] Prem K, van Zandvoort K, Klepac P, Eggo RM, Davies NG, Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, et al. Projecting contact matrices in 177 geographical regions: An update and comparison with empirical data for the COVID-19 era. PLoS Comput Biol 2021;17(7):e1009098. https://doi.org/10.1371/journal.pcbi.1009098
[58] Organization for Economic Co-operation and Development (OECD). Hours worked, ⟨https://www.oecd.org/en/data/indicators/hours-worked.html⟩ [accessed 24 January 2025].
[59] World population review. Average School Day Length by Country 2024, ⟨https://worldpopulationreview.com/country-rankings/average-school-day-length-by-country⟩ [accessed 24 January 2025].
[60] Yun J, Kim CY, Son S-H, Bae C-W, Choi Y-S, Chung S-H. Birth rate transition in the Republic of Korea: trends and prospects. J Kor Med Sci 2022;37(42). https://doi.org/10.3346/jkms.2022.37.e304
[61] Gruhn S, Batram M, Wick M, Langevin E, Scholz S, Greiner W, et al. Modelling the Public Health Impact of MenACWY and MenC Adolescent Vaccination Strategies in Germany. Infect Dis Ther 2024;13(4):907–20. https://doi.org/10.1007/s40121-024-00958-7
[62] Riva MA, Paladino ME, Paleari A, Belingheri M. Workplace COVID-19 vaccination, challenges and opportunities. Occup Med 2022;72(4):235–7. https://doi.org/10.1093/occmed/kqab080
[63] Brinton MC, Oh E. Babies, work, or both? Highly educated women's employment and fertility in East Asia. Am J Socio 2019;125(1):105–40. https://doi.org/10.1086/704369
[64] te Braak P, van Tienoven TP, Minnen J, Glorieux I. Data quality and recall bias in time-diary research: The effects of prolonged recall periods in self-administered online time-use surveys. Socio Method 2023;53(1):115–38. https://doi.org/10.1177/00811750221126499
[65] Eames KT, Tilston NL, Edmunds WJ. The impact of school holidays on the social mixing patterns of school children. Epidemics 2011;3(2):103–8. https://doi.org/10.1016/j.epidem.2011.03.003c