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The impact of physical distancing measures against COVID-19 transmission on contacts and mixing patterns in the Netherlands: repeated cross-sectional surveys

--Manuscript Draft--

Manuscript Number:	
Full Title:	The impact of physical distancing measures against COVID-19 transmission on contacts and mixing patterns in the Netherlands: repeated cross-sectional surveys
Article Type:	Research
Keywords:	COVID-19; SARS-CoV2; coronavirus; mixing patterns; physical distancing; contact survey
Corresponding Author:	5.1.2e Rijksinstituut voor Volksgezondheid en Milieu Bilthoven, NETHERLANDS
Corresponding Author's Institution:	Rijksinstituut voor Volksgezondheid en Milieu
First Author:	5.1.2e
Order of Authors:	5.1.2e 5.1.2e 5.1.2e 5.1.2e 5.1.2e 5.1.2e
Abstract:	Background During the current pandemic of coronavirus (COVID-19) many countries have taken drastic measures to reduce transmission of SARS-CoV2. The measures often include physical distancing that aims to reduce the number of contacts in the population. Little is known about the actual reduction in number of contacts as a consequence ofphysical distancing measures. Methods In the Netherlands, a cross-sectional survey was carried out in 2016/2017 in which 8179 participants retrospectively reported the number, age and gender of different persons they had contacted (spoken to in person or touched) during the previous day. The survey was repeated in March and April 2020 among 2830 of the original participants, using the same questionnaire, after physical distancing measures had been implemented. Results The average number of contacts in the community was reduced from on average 12.5 (interquartile range: 2-17) to 3.7 (interquartile range: 0-4) different persons per participant, a reduction of 71% (95% confidence interval: 71-71). The reduction in the number of community contacts was highest for children and adolescents (between 5 and 20 years) and smallest for elderly persons of 80 years and older. The reduction in the effective number of total contacts, measured as the largest eigenvalue of the matrix with community and household contacts, was 62% (95% confidence interval: 48 - 72). Conclusion The substantial reduction in contacts has contributed greatly in halting the COVID-19 epidemic. This reduction was unevenly distributed over age groups, household sizes and occupations. These findings offer guidance for the lifting of age-group targeted measures.
Suggested Reviewers:	5.1.2e 5.1.2e@ispm.unibe.ch 5.1.2e 5.1.2e@lshtm.ac.uk Pietro Coletti 5.1.2e@uhasselt.be

	5.1.2e 5.1.2e @inserm.fr
Opposed Reviewers:	
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Word count of the text	2748
Has informed consent has been obtained from persons whose details are described in your manuscript (or from the persons' guardians) that this information may be published?	Yes
If the answer to the above question is no, explain here why informed consent was not obtained.	
Please copy/paste your covering letter here.	Dear Editor, We would appreciate the consideration of our manuscript "The impact of physical distancing measures against COVID-19 transmission on contacts and mixing patterns in The Netherlands: repeated cross-sectional surveys" for publication as fast track research article in Eurosurveillance. Allmost all countries and regions around the world have taken drastic measures to curb the COVID-19 epidemic effectively. An essential component of these measures is physical distancing, which aims to reduce the number of contacts in the population. We know of only two studies that attempted to measure the effectiveness of physical distancing in terms of reducing the number of contacts. Because of the sudden emergence of the epidemic, such studies could not follow any traditional design and have limited number of participants. One study in China had to rely on recall for over 48 days to measure the number of contacts before the implementation of physical distancing (Zhang et al., Science 2020); the other study in the UK relied on a 14 year-old study to provide a baseline for the number of contacts before the implementation of physical distancing (Jarvis et al., BMC Med 2020). Here we present a study that overcomes these methodological issues, and that measures contact patterns among a large sample of participants. This manuscript compares the results of two successive contact surveys in the same study population in the Netherlands, using an identical study design: a survey with over 8000 participants in 2016 and 2017 which serves as a baseline, and a survey with almost 3000 participants in March and April 2020, just after physical distancing measures were implemented. We provide a detailed report of how the substantial reductions in number of contacts between surveys vary with age, household size, and occupation. We estimate the number of contacts between and within age groups, to show how physical distancing affects contact patterns in the population. We provide these estimates as supplementary material such that they can be used in infectious disease models. We believe our results will provide essential information for developing infection control strategies in the next phase of the epidemic, when the most drastic control measures might be lifted. For this reason, we'd appreciate a fast track peer review and publication process. We believe these results will be of great interest to the wide

	scientific audience, including public health policy makers, infectious disease specialists, and modelers, that is addressed by Eurosurveillance. Thank you for taking the time to consider our manuscript. Please let us know if we can be of assistance during the review process. All authors have read and approved the final manuscript for submission. 5.1.2e (on behalf of all authors)
If a collective author is included (e.g. a working group or disease-specific network) and if the persons comprising the group are to be included at the end of the article, please list each person here. The contribution of the collective author should be stated in the relevant section.	
Authors' contributions: the contribution of each author to the article, including collective author if applicable, should be described here. This information will appear at the end of the published article.	JB: data analysis, investigation, data visualisation, writing first draft; LM: data curation, investigation, review; DK: methodology, review; FvdK: funding acquisition, project administration, review; HdM: funding acquisition, project administration, review; SvdH: supervision, review; JW: conceptualisation, methodology, review
Please include any acknowledgements here. You may acknowledge anyone who has helped you with any aspect of the report, but it is always the corresponding author's responsibility to obtain permission from anyone being acknowledged.	We gratefully acknowledge the participants of the contact surveys in 2016/2017 and 2020, as well as Dr. S. A. McDonald for critically assessing the manuscript.
Have these findings already been published or is publication of these findings planned in a different format (e.g.: national or European report)?	no
Do you have any conflicts of interest regarding your manuscript? If yes, please specify. If no, enter 'None'.	None
Have the nucleic acid sequence data been deposited in sustainable, public, and open access, databases?	No
Manuscript Classifications:	The Netherlands; viral infections; respiratory infections; respiratory viruses; infection control; outbreaks; epidemiology; modelling
Author Comments:	

Title page

Title: The impact of physical distancing measures against COVID-19 transmission on contacts and mixing patterns in the Netherlands: repeated cross-sectional surveys

Authors: Jantien 5.1.2e
5.1.2e

Affiliations

1 Centre for Infectious Disease Control, National Institute for Public Health and the Environment, Bilthoven, The Netherlands

2 Department of Biomedical Data Sciences, Leiden University Medical Center, Leiden, The Netherlands

Corresponding author: 5.1.2e

Corresponding author email: 5.1.2e @rivm.nl

Abstract

Background

During the current pandemic of coronavirus (COVID-19) many countries have taken drastic measures to reduce transmission of SARS-CoV2. The measures often include physical distancing that aims to reduce the number of contacts in the population. Little is known about the actual reduction in number of contacts as a consequence ofphysical distancing measures.

Methods

In the Netherlands, a cross-sectional survey was carried out in 2016/2017 in which 8179 participants retrospectively reported the number, age and gender of different persons they had contacted (spoken to in person or touched) during the previous day. The survey was repeated in March and April 2020 among 2830 of the original participants, using the same questionnaire, after physical distancing measures had been implemented.

Results

The average number of contacts in the community was reduced from on average 12.5 (interquartile range: 2-17) to 3.7 (interquartile range: 0-4) different persons per participant, a

reduction of 71% (95% confidence interval: 71-71). The reduction in the number of community contacts was highest for children and adolescents (between 5 and 20 years) and smallest for elderly persons of 80 years and older. The reduction in the effective number of total contacts, measured as the largest eigenvalue of the matrix with community and household contacts, was 62% (95% confidence interval: 48 - 72).

Conclusion

The substantial reduction in contacts has contributed greatly in halting the COVID-19 epidemic. This reduction was unevenly distributed over age groups, household sizes and occupations. These findings offer guidance for the lifting of age-group targeted measures.

Keywords: COVID-19; SARS-CoV2; coronavirus; mixing patterns; physical distancing; contact survey

Conflict of interest: 'None declared'

Funding statement: The study was financed by the Netherlands Ministry of Health, Welfare and Sport. This project has received funding from the European Union's Horizon 2020 research and innovation programme - project EpiPose (grant agreement number 101003688).

Ethics approval and consent to participate

The MEC-U (Medical Research Ethics Committees United; R20.022) has approved the research protocol "Third population-based immune surveillance study used for the evaluation of immunity against SARS-CoV-2' (PIENTER Corona)" and written informed consent was obtained from all adult participants, and parents or legal guardians of minors included in the study.

Acknowledgments

We gratefully acknowledge the participants of the contact surveys in 2016/2017 and 2020, as well as Dr. S. A. McDonald for critically assessing the manuscript.

Abstract

Background

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Introduction

Since the beginning of 2020, the novel coronavirus SARS-CoV2 that causes COVID-19 disease has rapidly spread around the world. Most patients experience mild symptoms, but in particular elderly and persons with comorbidities may develop severe acute respiratory disease [1]. Hospitals have been confronted with an alarmingly growing number of patients, often exceeding the intensive care (IC) capacity. Many countries have implemented control measures that include a combination of increased hygiene, travel restrictions, case finding, contact tracing and physical distancing measures. The specific physical distancing measures differ between countries and between regions; their overall aim is to reduce the number of contacts in the population thus preventing the transmission of infection. The impact of these measures on the reduction of contacts in the population, and the reduction of contacts made by different age groups within that population, are poorly quantified.

Different approaches exist to measure behavioural changes. Mobile telephone data provided by telecom companies are used to measure the change in mobility patterns [2, 3]. Similarly, the location history of smart phones can be tracked with apps [4]. The anonymised and aggregated mobility patterns can suggest changes in contact patterns in the population at large. To obtain direct and detailed information on contacts, cross-sectional studies are conducted in which participants report their age and gender as well as the age and gender of all persons they have contacted during a single day [5, 6]. Contact surveys have been successfully used to quantify the reduction in the number of contacts associated with physical distancing measures in Shanghai and Wuhan, China, estimated at 88% and 86%, respectively [7], and in the UK [8] among the adult population, at 74%. One of the challenges with the contact survey approach is to obtain a reliable baseline measurement before physical distancing measures were implemented. In the Wuhan study participants needed to recall the number of contacts during a regular weekday at the end of 2019. In the UK study the baseline was provided by a similar study conducted 13 years ago among a different representative UK study population [5].

We present a large contact survey conducted in the Netherlands in March and April 2020. The participants were recruited from a large sample of the Dutch population who had participated in an earlier large cross-sectional survey in 2016/2017 [9]. The contact questionnaire was nearly identical in both surveys, which allows us to use the first survey as

a baseline measurement, and the second survey as a measurement of contacts during the implementation of physical distancing measures. By 16 March, the Netherlands had imposed physical distancing measures including closing daycare centers, schools, universities; working from home whenever possible; closing of cafes, pubs, restaurants, theaters, cinemas, and sport clubs; cancelling events with more than 10 persons attending; maintaining 1.5 m distance from others outside one's household.

By comparing the survey results before and after the implementation of these physical distancing measures, we could determine the impact on the number of contacts made in the community (i.e. outside the household), distinguishing between different age groups, genders, household sizes, days of the week and occupations. We also assessed how the physical distancing measures have affected the total number of contacts, including contacts with household members, and the age-specific mixing patterns.

Methods

Between February 2016 and October 2017, a cross-sectional study was conducted in a sample of the Dutch population from 0 to 89 years of age [9], henceforth referred to as the baseline survey. Participants were randomly selected from the Dutch population registry using a two-stage cluster design. Infants under 1 year of age, persons living in areas with low vaccination coverage, and persons with a migration background were oversampled in this survey. The study consisted of an extensive questionnaire, and included questions regarding the participants' age, gender and occupation, the age and gender of their household members, and the total number of unique persons they had contacted outside their household the previous day and which day of the week (i.e., Monday through Sunday) that was. Participants reported the age of the contacted persons in 11 age groups (0-4, 5-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-89, 90+). A contact was defined as a conversation in person, or physical contact.

Of the 8179 participants that had filled out the questionnaire in 2016/2017, 6712 had indicated to be willing to participate in future research. Of these, 6102 were invited on 26 March 2020 to participate in the follow-up study, referred to as 'the physical distancing survey'. As of 26 April 2020, 2830 had returned a questionnaire. Participants not reporting

their household composition or reporting more than 100 contacts were excluded from the analysis.

The questionnaire in the physical distancing survey was identical to the baseline survey questionnaire, apart from two questions. A question asking whether participants had had any contacts outside their household was added (before asking how many), and the question about occupation was changed to cover occupations that involve many contacts and that are part of vital processes.

We analysed the baseline and physical distancing contact surveys by comparing the number of contacts in the community per participant stratified by several characteristics: age, gender, household size, day of the week, and occupation (as reported in the physical distancing survey, under the assumption that participants did not change occupation between the two surveys).

We obtained the total number of contacts in the population by adding contacts with reported household members to the reported contacts in the community. We estimated age-stratified contact matrices that contain the number of contacts made between and within age groups, using an approach that accounts for reciprocity of contacts between different age groups [10], and using age-specific population size data for the Netherlands on 1 January 2017 and on 1 January 2019 [11]. To check the effect of enforcing reciprocity between contacts, we compared the estimated and observed mean number of contacts per participant.

We characterised the mixing pattern of the age-specific contacts by the disassortativeness index [12], and characterised the effective number of age-specific contacts by the largest eigenvalue of the contact matrix [13].

All analyses were done using R version 3.6.0 [14].

Results

Characteristics of the study population

In total 7548 baseline survey participants and 2698 physical distancing survey participants were included for analysis. The composition of the survey population by age and gender reflected the Dutch population (Figure 1). The mean age was 35 years (range 0 – 88) in the baseline survey, and 39 years (range 3 – 87) in the physical distancing survey. Each age group consisted of more than 100 participants in both surveys, except for the 80+ age group in the physical distancing survey (Table 1). The household size distribution for the baseline survey population reasonably reflects the household size distribution in the Netherlands [15], whereas the household size distribution for the physical distancing survey population contained relatively few single-person households. The reported average household size of 2.8 in the baseline survey is smaller than the reported average household size of 3.3 in the physical distancing survey. There were more than 100 participants reporting their contacts for each day of the week, for both surveys.

Reduction in the mean number of contacts in the community

The percentage of participants who did not report any community contacts increased from 17% in the baseline survey to 41% in the physical distancing survey. On average, a participant had 12.5 (2 – 17, interquartile range or IQR) community contacts per day in the baseline survey, and 3.7 (0 – 4) community contacts in the physical distancing survey (Tab. 2).

In the baseline survey, participants aged 10 to 19 years had the highest number of contacts, and this number gradually declined with increasing age. In contrast, the number of contacts was similar across the different age categories in the physical distancing survey (Fig. 2). The reduction in the number of contacts was greatest for participants aged 5 to 9 years, and lowest for participants aged 80 to 89 (Tab. 2).

The reduction in the mean number of contacts was similar for male and female participants. The number of community contacts increased with household size in the 2017 survey, whereas this number was similar for the different household sizes in 2020. In the baseline

survey, most contacts were made during weekdays, slightly fewer on Saturdays and fewest on Sundays. The reduction of contacts between the two surveys was similar for all days of the week, except for Saturdays, when participants decreased their contacts to a lesser extent.

The reduction in contacts varied between participants depending on their occupation. Among the occupations represented by more than 40 participants, the greatest reduction was observed for schoolchildren and students, and the lowest reduction for those working in food industry, retail and health care.

Comparison of mixing patterns

In the estimation of the contact rates between age groups, the reciprocity between contacts was explicitly taken into account. The observed and estimated mean numbers of community contacts per participant are in agreement (Fig. 2), showing that participants accurately reported their contacts.

The contact matrices for both contact surveys and for the different types of contact (community, household) are shown in Fig. 3. The contact matrices for household members illustrate how participants live with persons in their own age category and with their children or parents (i.e., 30 years younger and older); this is apparent in both baseline and the physical distancing surveys. The matrices for contacts in the community indicate fewer contacts within the younger age groups in the physical distancing survey compared with the baseline survey. In the physical distancing survey, persons of 80 years and older had a relatively large number of community contacts with age groups from 50 to 79 years old. In this survey, 85% of the contacts with persons of 80 years and older were reported by health care workers. Taken together, the household and community contact patterns reveal that age-specific mixing did not change much between the baseline and the physical distancing surveys (disassortativeness index is 0.53 for the baseline and 0.54 for physical distancing survey). However, the effective number of contacts per person (i.e. the largest eigenvalue of the contact matrix) decreased from 16 (14 – 21, 95% credible interval) in the baseline survey to 6.1 (5.4 – 7.7) in the physical distancing survey, an average reduction of 62% (48 – 72).

Discussion

In the Netherlands, physical distancing measures came into effect on 16 March 2020. Three weeks after implementation, the numbers of occupied hospital and IC beds reached a peak, after which they gradually declined. Through comparison with the baseline survey, physical distancing measures were estimated to have drastically reduced the numbers of contacts in the community, by 71%. The reduction in the mean number of community contacts varied with occupation, and are larger for younger age groups, larger household sizes, and weekdays as compared to weekends. The effective number of the total contacts per person decreased by 62%.

This effective number of contacts per person is proportional to the reproduction number (i.e. the number of secondary infections caused by a single infectious person in the population) under two conditions. First, the definition of contact (having a conversation in person or physical contact) is a good proxy measure for at-risk contact events where SARS-CoV-2 can be transmitted. Second, all age groups are equally susceptible and infectious. As evidence accrues that children are less infectious or less susceptible [7, 16], and children report a larger reduction in contacts compared with other age-groups after imposition of physical distancing, a reduction in the effective number of contacts represents an upper bound for the reduction of the reproduction number. This, in turn, implies that the physical distancing measures that reduce the effective number of contacts by 62%, are sufficient to reduce a reproduction number with values up to 2.6, to 1 or lower, and halt the COVID-19 epidemic.

Elderly persons had a relatively small reduction in their number of contacts. Most of their reported contacts after the implementation of physical distancing measures were with health care workers. These remaining contacts are likely essential, and there is little prospect for further reducing the number of contacts for this age group. Measures other than physical distancing are required to protect the elderly who are the most susceptible to infection [7] and have the highest risk of complications [1].

The study participants were randomly sampled from the Dutch population in 2016, with oversampling of zero-year olds, persons living in a low vaccination coverage area, and person with a migration background. We have identified the following limitations. Not all

participants of the baseline survey indicated that they would participate in a follow up, and not all of those who were invited participated. For instance, 90% of participants in the physical distancing survey were indigenous Dutch, compared to 78% in the baseline survey [9]. Apart from the potential for selection bias, there are differences in participant characteristics between the baseline study in 2016/2017 and the physical distancing survey in 2020, and these differences may have affected the results. First, the physical distancing survey participants were older, because they had aged in the intervening 3.5 years, with the consequence that the physical distancing survey did not contain any 0 to 2 year olds. To assess the effect on the mean number of contacts, we created a synthetic population with the size and age distribution of the physical distancing population, sampled from the baseline population. This synthetic population has on average 13.2 (12.7 – 13.8, 95% bootstrap interval) community contacts per participant, which is higher than the baseline population with a mean of 12.5 community contacts per participant. This means that the contact reduction may have been underestimated. Second, the physical distancing survey participants reported a larger household size on average, which resulted in a greater number of household contacts. Third, the physical distancing participants reported their contacts more often on weekdays (85% versus 64% in the baseline survey), which would result in an underestimation of the reduction in the number of contacts. Fourth, the physical distancing survey was carried out in two months in spring, whereas the baseline survey was conducted over a period of almost two years. Because contact patterns change little throughout the course of a year [17], we do not expect this to substantially affect the estimated reduction. Fifth, the additional question in the physical distancing survey questionnaire that asked beforehand whether the participants had had any contacts allowed us to check the reliability of their reported number of contacts. The reported number of contacts in the baseline survey, without such a check, may have been larger. All these differences together may have led to a slight underestimation in the reduction in the number of contacts.

The reduction in the number of contacts associated with physical distancing measures in the Netherlands is smaller than the reductions of 88% and 86% observed in Shanghai and Wuhan, China [7], most probably because of the complete lockdown in both cities. In the UK a 74% reduction in the number of all contacts among adults (18+) has been reported [8]. To

compare this with our results, we calculated the total number of contacts including community and household contacts for the participants in our surveys who are 18 years and older, and found a reduction of 56%. At the time of the studies the control measures in the UK and the Netherlands ranked at similar values of the stringency index [18]. The effect on contact reduction differs, possibly due to study population differences or compliance.

The results of this study have immediate application for a number of important issues of concern to the public health response and management of the COVID-19 pandemic. The estimated contact reduction is applicable to other countries and regions with similar control measures. The estimated age-specific contact matrices are useful for conducting scenario analyses with age-structured transmission models of COVID-19, to project the future course of the epidemic under physical distancing measures, and to explore the possible effects of lifting them [19, 20]. As we plan to repeat the contact survey at regular intervals, we will be able to monitor the number of contacts made over time, and detect the impact of future changes in these measures such as the reopening of schools, as well as changes in compliance with the measures that remain. We believe that contact surveys such as these can help to inform and guide infection control measures in this time of unprecedented physical distancing, and in the next phase of the epidemic, when the most drastic control measures might be lifted.

Supplementary material

Data of contact matrices shown in Fig. 3 are available as tab separated file (S1_contact_matrices.tsv).

References

[1] China CDC The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19)—China, 2020, Vital Surveillances - China CDC Weekly, 2020 available from cdn.onb.it

[2] 5.1.2e 5.1.2e 5.1.2e Mobile phone data for informing public health actions across the COVID-19 pandemic lifecycle. Science Advances 2020 10.1126/sciadv.abc0764

[3] 5.1.2e COVID-19 outbreak response: a first assessment of mobility changes in Italy following national lockdown. medRxiv 2020 doi: 10.1101/2020.03.22.20039933

[4] Google 2020, Covid-19 Community Mobility Reports, available from https://www.google.com/covid19/mobility/

[5] 5.1.2e 5.1.2e Social contacts and mixing patterns relevant to the spread of infectious diseases. PLoS Med. 2008 Mar 25;5(3):e74. doi: 10.1371/journal.pmed.0050074.

[6] 5.1.2e A Systematic Review of Social Contact Surveys to Inform Transmission Models of Close-contact Infections. Epidemiology. 2019 Sep;30(5):723-736. doi: 10.1097/EDE.0000000000001047.

[7] 5.1.2e 5.1.2e Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. *Science* 29 Apr 2020: eabb8001 doi: 10.1126/science.abb8001

[8] 5.1.2e CMMID COVID-19 working group, 5.1.2e 5.1.2e Quantifying the impact of physical distance measures on the

transmission of COVID-19 in the UK. *BMC Med* 18, 124 (2020). doi.org/10.1186/s12916-020-01597-8

[9] 5.1.2e 5.1.2e Third national biobank for population-based seroprevalence studies in the Netherlands, including the Caribbean Netherlands. BMC Infect Dis. 2019 May 28;19(1):470. doi: 10.1186/s12879-019-4019-y.

[10] 5.1.2e Efficient estimation of age-specific social contact rates between men and women Ann. Appl. Stat Volume 11, Number 1 (2017), 320-339

[11] Statistics Netherlands 2019; population composition, available from: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37296ned (accessed April 2020)

[12] 5.1.2e Measures of disassortativeness and their application to directly transmitted infections. Biom J. 2009 Jun;51(3):387-407. doi: 10.1002/bimj.200800160.

[13] 5.1.2e The construction of next-generation matrices for compartmental epidemic models. J R Soc Interface. 2010 Jun 6;7(47):873-85. doi: 10.1098/rsif.2009.0386.

[14] R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

[15] Statistics Netherlands 2019; household sizes and composition, available from: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/71486NED (accessed April 2020)

[16] 5.1.2e 5.1.2e 5.1.2e 5.1.2e 5.1.2e 5.1.2e 5.1.2e Spread of SARS-CoV-2 in the Icelandic Population. N Engl J Med. 2020 Apr 14. doi: 10.1056/NEJMoa2006100.

[17] 5.1.2e 5.1.2e The French Connection: The First Large Population-Based Contact Survey in France Relevant for the Spread of Infectious Diseases. PLoS One. 2015 Jul 15;10(7):e0133203. doi: 10.1371/journal.pone.0133203.

[18] 5.1.2e (2020). Oxford COVID-19 Government Response Tracker, Blavatnik School of Government. Available from https://covidtracker.bsg.ox.ac.uk/ (accessed April 2020).

[19] 5.1.2e 5.1.2e, 5.1.2e ; Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, 5.1.2e The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. Lancet Public Health. 2020 Mar 25. pii: S2468-2667(20)30073-6. doi: 10.1016/S2468-2667(20)30073-6

[20] 5.1.2e et al.. Estimating the burden of SARS-CoV-2 in France. 2020. pasteur-02548181, available from hal-pasteur.archives-ouvertes.fr/pasteur-02548181

Table 1 Participant characteristics for the baseline survey in 2016/2017 and the physical distancing survey in March and April 2020 in the Netherlands.

	2017		2020	
	n	(%)	n	(%)
Total	7548	(100)	2698	(100)
Participant age group				
0 – 4	1044	(13.8)	203	(7.5)
5 – 10	470	(6.2)	141	(5.2)
10 – 20	844	(11.2)	235	(8.7)
20 – 30	1080	(14.3)	341	(12.6)
30 – 40	925	(12.3)	418	(15.5)
40 – 50	844	(11.2)	401	(14.9)
50 – 60	788	(10.4)	423	(15.7)
60 – 70	865	(11.5)	314	(11.6)
70 – 80	567	(7.5)	193	(7.2)
80 – 90	121	(1.6)	29	(1.1)
Participant gender				
Female	4134	(54.8)	1520	(56.3)
Male	3414	(45.2)	1178	(43.7)
Household size*				
1	1474	(19.5)	198	(7.3)
2	2527	(33.5)	819	(30.4)
3	977	(12.9)	451	(16.7)
4	1499	(19.9)	789	(29.2)
5	695	(9.2)	311	(11.5)
6+	376	(5.0)	130	(4.8)
Contact day				
Monday	1178	(15.6)	677	(25.1)
Tuesday	1096	(14.5)	727	(26.9)
Wednesday	675	(8.9)	500	(18.5)
Thursday	355	(4.7)	260	(9.6)
Friday	549	(7.3)	124	(4.6)
Saturday	856	(11.3)	108	(4.0)
Sunday	1285	(17.0)	302	(11.2)
(Missing)	1554	(20.6)	0	(0)

* Households in the Netherlands consist of 1 (38%), 2 (33%), 3 (12%), 4 (12%) and 5+ (5%) persons [15], leading to an expected distribution per participant to live in a 1 (17%), 2 (31%), 3 (17%), 4 (23%) or 5+ (12%) person household.

Table 2 Number of community contacts per participant in the baseline survey in 2016/2017 and the physical distancing survey in March and April 2020 in the Netherlands (mean and interquartile range), and the reduction in the mean number of contacts (mean and 95% confidence interval).

	2017		2020		Reduction (%)	
	mean	(IQR)	mean	(IQR)	mean	(95% CI)
Total	12.5	(2 - 17)	3.7	(0 - 4)	70.8	(70.8 - 70.8)
Participant age						
0 – 4	8.8	(2 - 11)	2.3	(0 - 3)	73.8	(73.3 - 74.0)
5 – 10	18.0	(3 - 31)	2.1	(0 - 3)	88.6	(88.4 - 88.8)
10 – 20	19.7	(4 - 31)	3.0	(0 - 4)	85.0	(84.7 - 85.3)
20 – 30	15.0	(4 - 20)	4.5	(0 - 6)	69.8	(69.5 - 70.1)
30 – 40	13.1	(3 - 17)	4.5	(0 - 6)	66.0	(65.7 - 66.2)
40 – 50	13.5	(3 - 18)	4.9	(0 - 5)	64.1	(63.7 - 64.4)
50 – 60	11.1	(1 - 14)	4.6	(0 - 6)	58.3	(58.0 - 58.7)
60 – 70	8.3	(1 - 10)	2.3	(0 - 3)	72.7	(72.3 - 73.1)
70 – 80	6.8	(1 - 8)	1.5	(0 - 2)	77.4	(76.5 - 78.3)
80 – 90	6.0	(0 - 6)	3.5	(0 - 1)	42.0	(26.8 - 57.0)
Participant gender						
Female	12.2	(2 - 16)	3.5	(0 - 4)	71.5	(71.4 - 71.6)
Male	13.0	(2 - 18)	3.9	(0 - 4)	69.9	(69.8 - 70.0)
Household size						
1	9.3	(0 - 12)	3.8	(0 - 3)	59.3	(58.2 - 60.3)
2	11.8	(2 - 15)	3.1	(0 - 3)	73.9	(73.7 - 74.0)
3	11.6	(3 - 15)	4.6	(0 - 5)	60.6	(60.3 - 61.0)
4	14.8	(4 - 20)	3.7	(0 - 4)	75.0	(74.9 - 75.1)
5	16.5	(4 - 26)	3.9	(0 - 5)	76.3	(76.0 - 76.6)
6+	16.5	(2 - 25)	3.1	(0 - 4)	81.1	(80.7 - 81.5)
Contact day						
Monday	15.3	(4 - 21)	3.4	(0 - 4)	77.7	(77.6 - 77.8)
Tuesday	16.2	(4 - 23)	3.9	(0 - 4)	75.8	(75.6 - 75.9)
Wednesday	15.2	(4 - 21)	4.0	(0 - 4)	74.0	(73.7 - 74.2)
Thursday	16.7	(4 - 24)	4.0	(0 - 5)	76.0	(75.7 - 76.4)
Friday	16.2	(4 - 22)	3.9	(0 - 5)	76.2	(75.6 - 76.5)
Saturday	12.8	(4 - 17)	4.6	(0 - 5)	63.8	(62.5 - 65.0)
Sunday	10.0	(3 - 12)	2.4	(0 - 3)	76.4	(75.9 - 76.8)
(Missing)	6.4	(0 - 6)	n.a.		n.a	
Occupation						
Not working (n = 538)	9.5	(3 - 12)	1.7	(0 - 2)	82.3	(82.1 - 82.5)
Health care (n = 461)	16.8	(5 - 24)	5.7	(0 - 8)	66.0	(65.7 - 66.2)
Education (n = 171)	20.4	(5 - 30)	3.5	(0 - 4)	82.8	(82.2 - 83.1)
School children/students (n = 112)	17.6	(6 - 24)	2.0	(0 - 2)	88.6	(88.2 - 89.0)
Food industry (n = 93)	17.2	(4 - 24)	7.1	(0 - 8)	58.7	(56.8 - 60.6)
Government (n = 75)	15.7	(4 - 22)	2.2	(0 - 3)	85.8	(85.0 - 86.4)
Retail (n = 71)	12.5	(3 - 16)	4.5	(0 - 4)	64.3	(61.9 - 66.5)

Youth and social workers (n = 47)	13.8 (6 - 18)	2.7 (0 - 4)	80.6 (79.3 - 81.8)
Child care (n = 43)	16.1 (6 - 20)	3.7 (0 - 6)	77.2 (75.3 - 78.9)
Catering industry (n = 41)	15.6 (5 - 22)	3.3 (0 - 5)	78.6 (76.8 - 80.4)
Media (n = 41)	13.1 (5 - 19)	2.3 (0 - 4)	82.5 (81.2 - 83.8)
Close-contact occupations (n = 27)	13.1 (3 - 18)	3.8 (0 - 4)	70.9 (65.4 - 76.1)
Emergency services (n = 21)	15.9 (6 - 21)	7.8 (1 - 8)	50.8 (41.4 - 59.3)
Fuel and waste transportation (n = 9)	7.1 (0 - 10)	8.1 (6 - 8)	-14.1 (-59.2 - 18.1)
Public transport (n = 5)	11.2 (6 - 18)	2.6 (0 - 2)	76.8 (58.2 - 91.7)
Other (n = 764)	15 (4 - 21)	3.8 (0 - 5)	74.6 (74.4 - 74.7)

Figure legends

Figure 1 Composition according to age and gender of 7548 participants in the baseline survey in 2016/2017, and 2698 participants in the physical distancing survey in 2020 in the Netherlands, and compared to the Dutch population in 2017 and 2019, respectively.

Figure 2 Number of community contacts per participant per age group from the baseline survey in 2016/2017 (red) and the physical distancing survey in 2020 (blue) in the Netherlands; shown are the estimated mean number of contacts after accounting for reciprocity in contacts (line) with the corresponding 95% credible interval (shaded area), and the direct means (size of points scaled to number of participants).

Figure 3 Estimated contact matrices for the baseline survey in 2016/2017 (left) and the physical distancing survey in 2020 (right) in the Netherlands, for all contacts, contacts in the community and contacts with household members.

Covering letter

National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

A. van Leeuwenhoeklaan 9
3721 MA Bilthoven
Postbus 1
3720 BA Bilthoven
www.rivm.nl

T 5.1.2e
F 5.1.2e
info@rivm.nl

18th of May, 2020

Dear Editor,

We would appreciate the consideration of our manuscript "The impact of physical distancing measures against COVID-19 transmission on contacts and mixing patterns in The Netherlands: repeated cross-sectional surveys" for publication as fast track research article in *Eurosurveillance*.

Allmost all countries and regions around the world have taken drastic measures to curb the COVID-19 epidemic effectively. An essential component of these measures is physical distancing, which aims to reduce the number of contacts in the population. We know of only two studies that attempted to measure the effectiveness of physical distancing in terms of reducing the number of contacts. Because of the sudden emergence of the epidemic, such studies could not follow any traditional design and have limited number of participants. One study in China had to rely on recall for over 48 days to measure the number of contacts before the implementation of physical distancing (Zhang et al., Science 2020); the other study in the UK relied on a 14 year-old study to provide a baseline for the number of contacts before the implementation of physical distancing (Jarvis et al., BMC Med 2020). Here we present a study that overcomes these methodological issues, and that measures contact patterns among a large sample of participants.

This manuscript compares the results of two successive contact surveys in the same study population in the Netherlands, using an identical study design: a survey with over 8000 participants in 2016 and 2017 which serves as a baseline, and a survey with almost 3000 participants in March and April 2020, just after physical distancing measures were implemented. We provide a detailed report of how the substantial reductions in number of contacts between surveys vary with age, household size, and occupation. We estimate the number of contacts between and within age groups, to show how physical distancing affects contact patterns in the population. We provide these estimates as supplementary material such that they can be used in infectious disease models.

We believe our results will provide essential information for developing infection control strategies in the next phase of the epidemic, when the most drastic control measures might be lifted. For this reason, we'd appreciate a fast track peer review and publication process. We believe these results will be of great interest to the

wide scientific audience, including public health policy makers, infectious disease specialists, and modelers, that is addressed by *Eurosurveillance*.

Thank you for taking the time to consider our manuscript. Please let us know if we can be of assistance during the review process.

All authors have read and approved the final manuscript for submission.

5.1.2e (on behalf of all authors)

306578

Figure 1

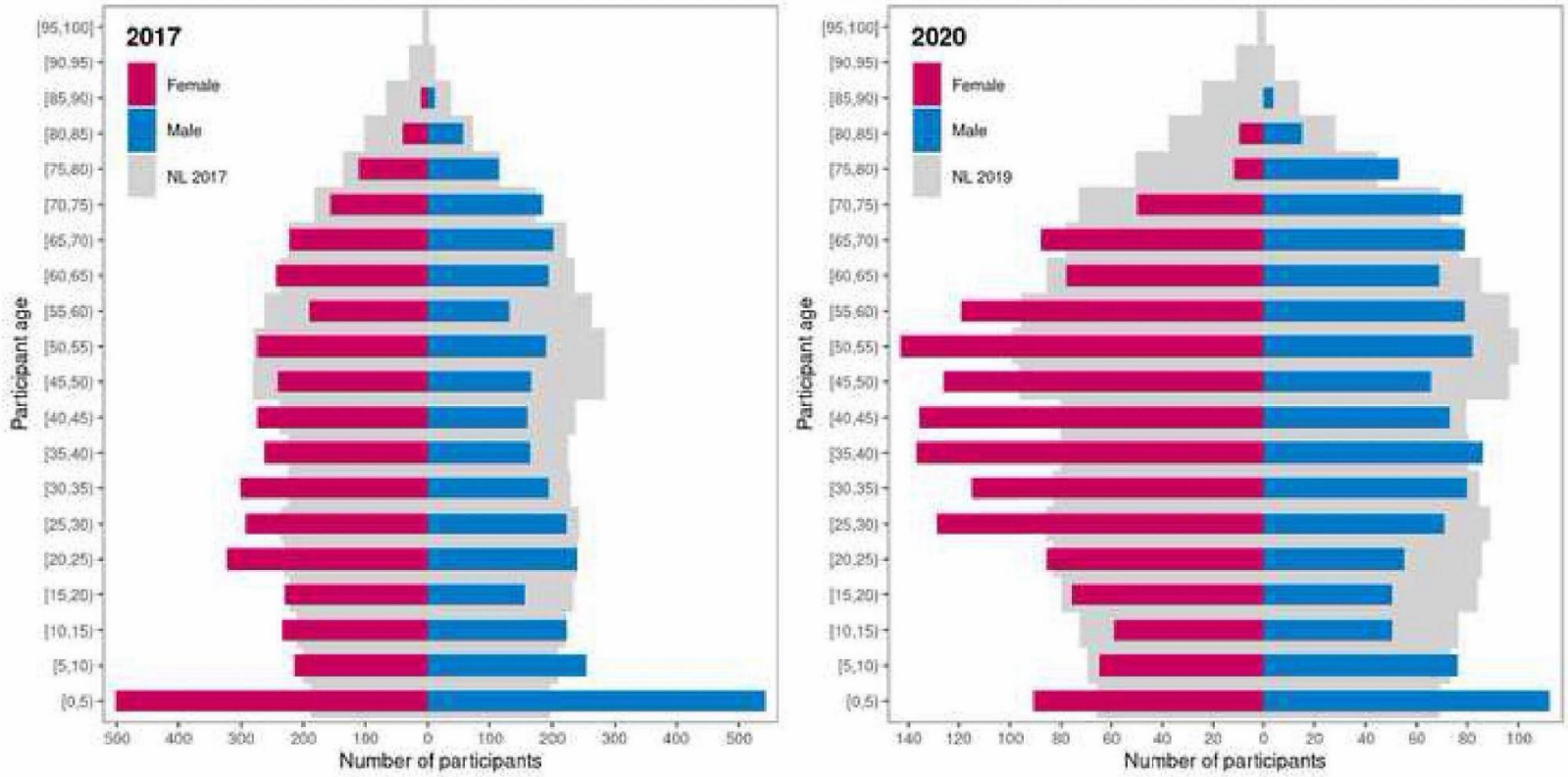


Figure 2

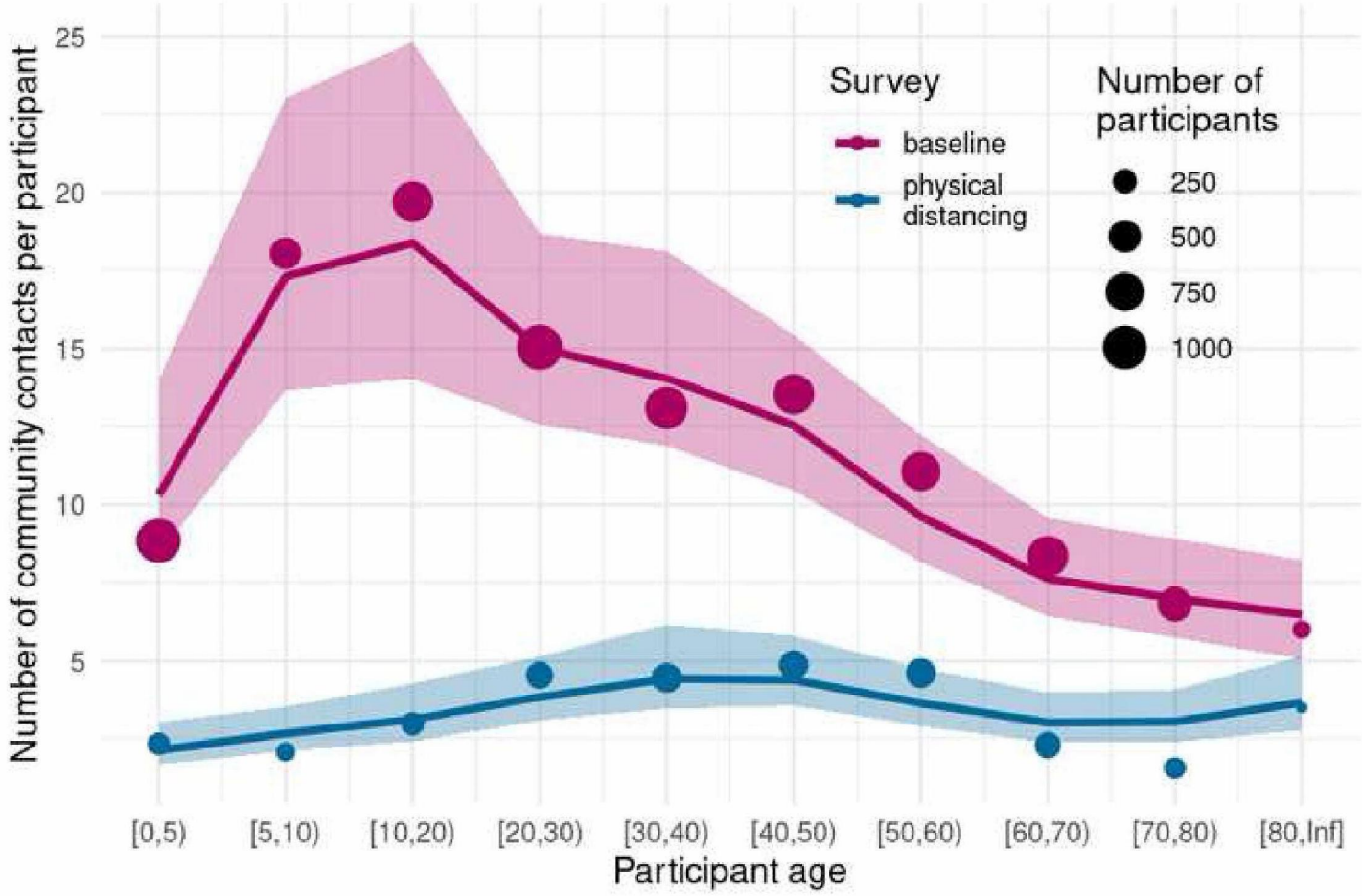
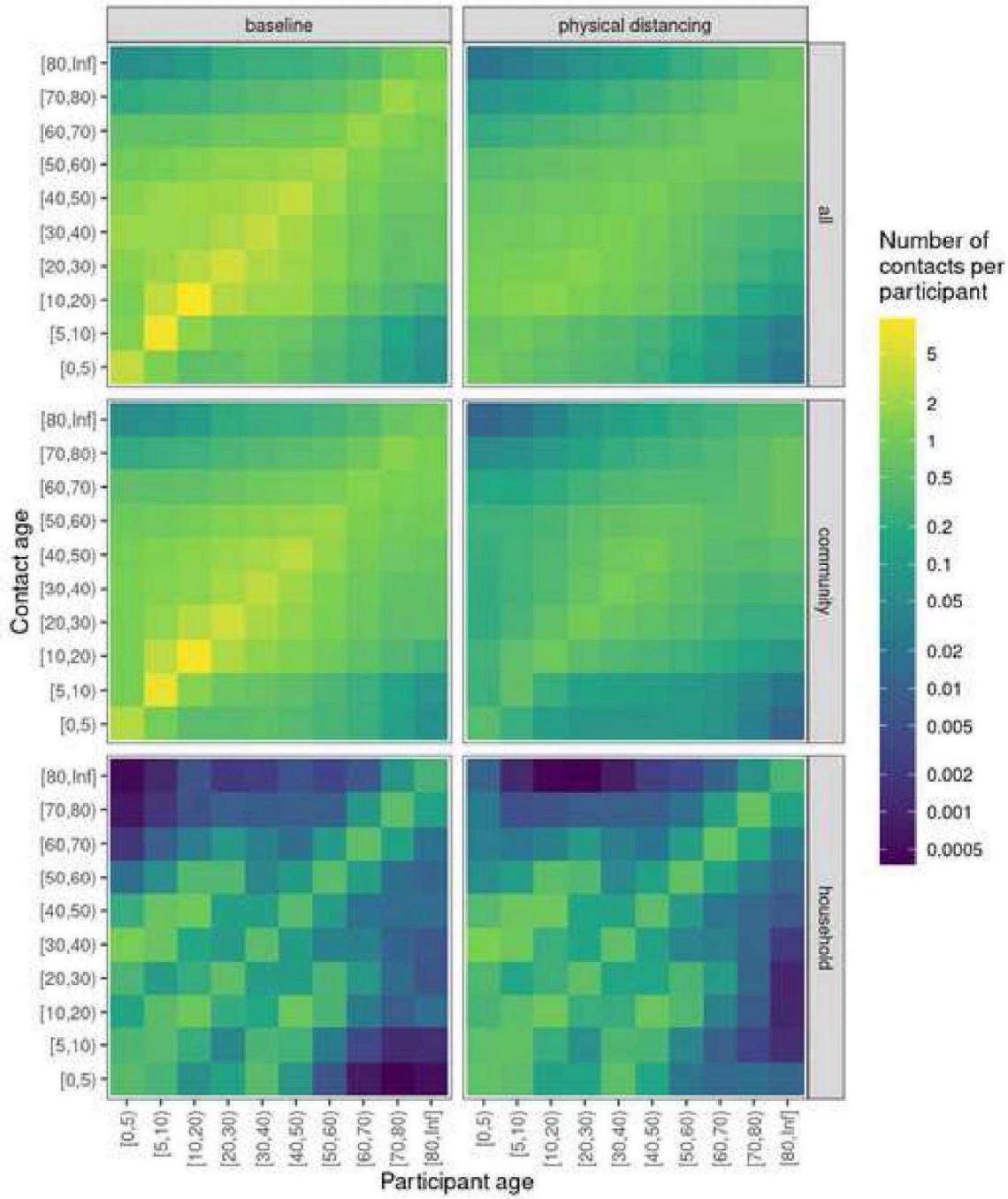

Number of community contacts per participant
25
20
15
10
5
Survey
baseline
physical distancing
Number of participants
250
500
750
1000
[0,5)
[5,10)
[10,20)
[20,30)
[30,40)
[40,50)
[50,60)
[60,70)
[70,80)
[80,Inf]
Participant age

Figure 3


baseline
physical distancing
all
community
household
Contact age
Participant age
[80,Inf]
[70,80)
[60,70)
[50,60)
[40,50)
[30,40)
[20,30)
[10,20)
[5,10)
[0,5)
Number of contacts per participant
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
0.0005

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Article title: The impact of physical distancing measures against COVID-19 and mixing transmission on contact patterns in the Netherlands: repeated cross-sectional surveys

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