Contact patterns of frail and non-frail elderly persons in the Netherlands during the COVID-19 pandemic

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Abstract

Background

During the COVID-19 pandemic social distancing measures were imposed to protect the population from exposure, especially elderly and frail persons who have the highest risk for severe outcomes. These restrictions greatly reduced contacts in the general population, but little is known about behaviour changes among elderly and frail persons themselves. Our aim was to quantify how COVID-19 measures affected contact behaviour of elderly and how this differed between frail and non-frail elderly.

Methods

In 2021 a contact survey was carried out among persons aged 70 years and older in the Netherlands. A random sample of persons per age group (70-74, 75-79, 80-84, 85-89, 90+) and gender was invited to participate, either during a period with stringent (April 2021) or moderate (October 2021) measures. Participants provided general information on themselves including their frailty, and reported characteristics of all persons with whom they had face-to-face contact on a given day, over the course of a full week.

Results

In total 720 community-dwelling elderly persons were included (overall response rate of 15%), who reported 16,505 contacts. During the survey period with moderate measures, non-frail participants had significantly more contacts outside their household than frail participants. Especially for women, frailty was a more informative predictor for number of contacts than age. During the survey period with stringent measures, frail and non-frail participants had significantly lower numbers of contacts compared to the survey period with moderate measures. The reduction of number of contacts was largest for the eldest non-frail participants.

As they likely interact closely with highly aged and highly frail persons, this reduction of number of contacts indirectly protects frail elderly from SARS-CoV-2 exposure.

Conclusions

The results of this study reveal that social distancing measures during the COVID-19 pandemic differentially affected the contact patterns of frail and non-frail elderly. The reduction of contacts may have led to direct protection of elderly persons in general but also to indirect protection of frail elderly.

Background

When the SARS-CoV-2 virus emerged at the end of 2019, it spread rapidly around the globe because of its ability to transmit presymptomatically and because the population was completely susceptible to this new virus. The only control option that could immediately mitigate the growing epidemic was the implementation of non-pharmaceutical interventions, including social distancing measures (e.g. closing schools, suspending leisure activities and working from home). These social distancing measures aim to reduce exposure by reducing contact rates, as each contact could be an at-risk event for transmission. Contact surveys show that in the first wave of the COVID-19 pandemic, contact rates decreased by more than half in China [1], the UK [2], the Netherlands [3] and other countries worldwide [4–7]. The reduction of contact rates effectively decreased the daily number of cases [8–10].

Social distancing was especially important to reduce exposure of old and frail persons, as they have the highest probability of hospitalisation and death after infection [11–13]. Frailty as a health status is a generic concept that can be defined and measured in many ways [14]. In hospital or care settings the focus is usually on physical frailty, expressed e.g. by the frailty index [15] or the Clinical Frailty Scale [16]. In general settings, frailty is often used in a broader sense that also comprises cognitive and psychosocial dimensions, expressed e.g. by the Tilburg Frailty Indicator [17] or Groningen Frailty Indicator [18]. All frailty instruments indicate that frailty increases with age, and is generally higher for women than men of the same age [19]. The variation in frailty among persons of the same age and gender is substantial, especially in community-dwelling elderly [20].

Two studies conducted in the Netherlands in 2006-2007 [21] and 2016-2017 [22] show that participants aged 70 years and older contact on average 7.3 (0 - 24) and 7.1 (0 - 19) different individuals per day (mean and 95% interval), respectively. Surveys among elderly during the first wave of the COVID-19 pandemic show a decrease in in-person contacts [23], associated with a decrease in general well-being [24], and an increase in frailty [25]. Contact surveys in the general population also showed a significant reduction of contact rates in older age groups [1–5]. However, none of these contact surveys distinguish participants by frailty.

We conducted a contact survey among persons aged 70 years and older in the Netherlands, taking their frailty status into account. General information such as age, gender and household size of the participants was collected, and their frailty status was measured using the Groningen

Frailty Indicator (GFI) [18]. In a contact diary, participants reported information on the face-to-face contacts they had on a each day of the week, yielding a snapshot of contact behaviour of the participant during a typical week. To our knowledge, this is the first contact study that quantifies the contact behaviour for individuals that differ not only in age but also in frailty.

The study encompasses two survey periods. The first survey period in April 2021 featured stringent COVID-19 control measures: education was online for most students of secondary schools and universities; working from home was required when possible; face masks were mandatory in indoor public spaces; bars and restaurants were closed, as well as all other cultural and leisure activities; and an evening curfew was in place. Most elderly persons had already had the opportunity to be vaccinated, but mass vaccination of the remaining adult population had only just started. In the second survey period in October 2021 most control measures had been lifted. Schools and work places were fully open; face masks were only required in public transport; and social, cultural and leisure venues were accessible with a proof of vaccination or negative test result. All persons aged 18 years and older were eligible for vaccination and many had been fully vaccinated. By conducting the survey during two distinct survey periods, we aim to gain insight in how frail and non-frail elderly change their contact behaviour when faced with lockdown measures.

Methods

Study design

Persons aged 70 years and older were invited to participate in the contact survey. For each survey period, invitees were randomly sampled from the Dutch Personal Records Database [26], yielding two independent cross-sectional study populations. The invitees were randomly sampled per age group (70-74, 75-79, 80-84, 85-89, 90+) and gender. The numbers of invitees were chosen to obtain similar numbers of respondents in each stratum, assuming lower response rates in older age groups. The questionnaires were unmarked to minimize the collection of personal data. As a consequence, it was not possible to send reminders to non-responders to increase response.

Each participant was requested to provide some general information and to fill out a contact diary during a full week. The general information consisted of participant age, gender, country of birth, education level, household size and vaccination status for COVID-19, influenza and invasive pneumococcal disease (IPD). To determine the frailty status of a participant, the Groningen Frailty Indicator (GFI) [18] was used. This indicator consists of 15 questions on physical, cognitive, social and psychological conditions. A GFI score of 4 or higher (out of 15) indicates a frail status. The GFI was preferred over other frailty indicators because it contains few questions and is easy to fill out.

The contact diary consisted of a contact page for each day of the week, where a participant could report all persons with whom they had face-to-face contact that day. A contact was defined as a short conversation and/or a physical contact; contacts via telephone or internet

were explicitly excluded. For each contacted person the participant reported the gender, age (range), whether this person was a household member, whether the contact was physical such as shaking hands, whether the contact was protected for example by a face mask, whether the contact lasted longer than 15 minutes, whether a minimal distance of 1.5 m was kept, and the location. Also, a name or description of the person could be reported, not only for ease of filling out but also to identify repeated contacts with the same person on different days of the week. Participants could indicate when they did not have any contacts on a given day, which was helpful to distinguish between participants without any contacts and participants that did not fill out the contact diary on that day. Returned questionnaires that lacked the general information and/or any filled out contact day were not included in further data processing. Questionnaires that were suitable for analysis were entered in a database with internal consistency checks, e.g. whether the participant is at least 70 years old and whether no duplicate participant id's are entered. After data cleaning, the data was reformatted to the standard format for contact surveys on socialcontactdata.org and published online [27]. A full description of all steps in the study design is provided in the supplement (Suppl S1). All code for data cleaning and analysis is publicly available [28].

Analysis

Response rates are calculated by age group and gender for both survey periods. The study population is described by summarising the number of responses by survey period, age group, gender, country of birth, GFI score, household size, and education level. To assess the bias of the study population, the number of participants not born in the Netherlands and the number of participants in long-term care facilities are compared to their expected values, based on the size of these groups living in the Netherlands in 2021 [29,30]. The observed vaccination coverages are compared to the actual vaccination coverages [31–33]. We evaluate which characteristics of the study population determine frailty (Suppl S2), and check whether this agrees with literature.

To focus the further analyses on community-dwelling elderly, participants that live in a long-term care facility are excluded. The contact behaviour is described by how many persons a participant contacted and in which age classes. For the analysis, only community contacts are included, i.e. contacts with non-household members, as these are the contacts that are mostly affected by control measures. The community contacts are summed over the full week to eliminate any day of the week effect. Participants with less than 5 completed days are excluded. The missing data of participants with 5 or 6 days completed, are imputed while taking the effects of the day of the week and fatigue into account (Suppl S3).

The weekly total of community contacts is assumed to follow a negative binomial distribution, where the log of the mean is modelled with full interactions between frailty (0 or 1), participant age (numeric), participant gender (M or F) and survey period (1 or 2). The COVID-19 vaccination status could also affect the number of contacts, but this covariate has been omitted because the data contains few unvaccinated participants. We assess whether household size (1 or 2+) should be included as an explanatory variable by comparing the likelihoods of the models with and without household size using a likelihood ratio chi-square test.

In a similar way, the effect of frailty in a specific period and the effect of the period on a specific frailty status are determined using subsets of the data. For example, the effect of frailty in the first survey period is assessed by comparing the likelihood of the model without frailty as an explanatory variable to the likelihood of the model with frailty, using only the data collected in the first survey period. If the likelihoods are similar (according to the chi-square test) the number of contacts does not significantly differ between frail and non-frail persons in the first survey period. The expected weekly total of community contacts are compared for an average frail and non-frail person in the Dutch 70+ population, by survey period.

To study age-specific mixing patterns, contact matrices are constructed by dividing the total number of contacts between two age groups by the number of participants in the participant age group. The resulting matrix of average numbers of contacts per participant is asymmetrical due to the skewed population distribution. We assume frail and non-frail persons mix proportionally and divide the matrix by the Dutch population distribution in 2021 [34]. Assuming reciprocal contacts, diagonally opposed matrix elements are averaged, yielding a symmetric contact matrix. The resulting contact rates can be interpreted as the average number of contacts per participant, if the population were uniformly distributed over the age groups.

We compare contact characteristics between frail and non-frail participants and between survey periods 1 and 2. For each contact it was reported whether it was unprotected (e.g. without a face mask), whether it lasted longer than 15 minutes, whether it was closer than 1.5 meters, and whether the contact was physical. For each of these four high-risk types, the fraction of community contacts per participant is calculated. Differences between the four comparison groups are tested with a Mann Whitney U test. In a similar way, the fraction of repeated community contacts per participant is analysed. Finally, the distribution over contact locations is compared visually between frailty status and survey period.

Results

Study population

In total 4914 invitations were sent out and 820 questionnaires were returned, of which 730 were suitable for analysis. The 90 questionnaires not suitable for analysis were either empty with sometimes an explanation why the invitee is not able or willing to participate (64), without general information (7), without any contact data (7), or incomprehensible (12). Response rates (Suppl S4) decreased by increasing age group, and were higher for men than for women. The overall response rate of survey period 1 (17%) was higher than for survey period 2 (13%).

The two survey periods consisted of similar numbers of participants (Tab. 1). The age group distribution of the study population ranges from 17% for the 90+ age group to 23% for the 85-89 age group, close to the aim of 20% for each of the five age groups. More men (56%) than women participated. A large majority (95%) of the participants were born in the Netherlands. Based on the number of Dutch citizens with a first generation migration background by age

group [29], we would expect 53 participants with another country of birth in the study population. Instead, only 34 participants were not born in the Netherlands, which cannot be explained by stochastic effects, indicating a lower response rate in this group.

Around one third of the participants had a frail status according to the GFI. Frailty is higher for women than for men in the same age group, and it increases with age but faster for men than for women (Fig. 1A). These findings agree with literature (Suppl S2) and results reported for the Tilburg Frailty Indicator of community-dwelling elderly [35], which is a frailty indicator similar to the GFI. Most participants (60%) lived with one or more household members. According to the number of Dutch elderly citizens in long-term care facilities [30], we would expect 60 participants in care. Instead, only 10 participants indicated that they live in a nursing home or similar long-term care facility, emphasizing that the study population is more representative of community-dwelling elderly. One-person households were more common for higher age groups and for women (Fig. 1B). The education level is, in general, higher for younger age groups and for men (Fig. 1C).

Participants reported whether they had been vaccinated in the last 12 months against COVID-19, influenza or IPD (Fig. 1D). The highest coverages were observed for COVID-19 in all age groups. Only the age group 70-74 fell slightly below other age groups in the first survey period in April 2021 as they had only just been invited for vaccination. The overall vaccination coverage in the study population in the second survey period in October 2021 (98%) was higher than the actual coverage reported for the 70+ population (93%) [31]. The overall vaccination coverage against influenza in the study population (75%) was higher than in the general 65+ population (73%) [32]. Nothing can be concluded from the IPD vaccination coverage, because the IPD vaccination programme for older adults has been implemented in 2020 for specific age groups [33].

Contact behaviour

For the contact behaviour analysis, 4 participants without frailty status, 10 participants in long-term care facilities and 12 participants who participated less than 5 days were excluded. Of the 704 included participants, 46 provided contact information for less than 7 days. The number of contacts on their missing days was imputed, while taking reductions in average number of contacts into account of 4% on each additional participation day and 20% on Sundays (Suppl S3). The household size did not affect the number of community contacts and is not included in the full model. By comparing full and subset formulations, we found some evidence that the number of contacts of frail and non-frail participants differed in survey period 1, though not statistically significant (p-value = 0.085), and differed significantly in survey period 2 (p-value = 0.023). The number of contacts between the two survey periods differed significantly for both frail (p-value = 0.0050) and non-frail (p-value < 0.0001) persons. According to the full model, the expected weekly number of community contacts in survey period 1 was 14 (12 - 17) (mean and 95% confidence interval) for an average frail person and 19 (16 - 21) for an average non-frail person. In survey period 2, they were 21 (17 - 25) for an average frail person and 26 (23 - 30) for an average non-frail person.

When plotting the full model results with all covariates (Fig. 2), we notice some remarkable patterns. The number of contacts in survey period 2 - with few COVID-19 measures - only slightly decreases with age in any stratum. Non-frail women have more contacts than frail women of any age, and frail men have the same number of contacts as 12-year older non-frail men. In survey period 1, frail persons of all ages decreased their contacts to a similar extent compared to survey period 2, demonstrated by the almost parallel lines in Fig. 2. For non-frail persons, however, the lines diverge, showing that the number of contacts in survey period 2 clearly decreased by age. This trend is obvious in both males and females.

The same effect is apparent in the contact matrices by frailty and survey period (Fig. 3). In all contact matrices the highest contact rates are on the diagonal, meaning that participants interact mainly with persons in the same age group. Frail participants have lower contact rates than non-frail participants, and in survey period 1 lower contact rates are observed than in survey period 2. The largest differences between survey period 1 and 2 are seen for older non-frail participants. In survey period 2 they interacted mainly with other older persons, from which they refrained in survey period 1.

Contact characteristics

Contact behaviour change is not only reflected in the number of community contacts, but also in the type of contacts. For all types of contacts, participants shifted to more risky behaviour in survey period 2 compared to survey period 1: the fraction of community contacts per participant that were without protection, closer than 1.5 m, lasting over 15 min and involved physical contacts increased significantly (Fig. 4). For the most part, differences between frail and non-frail participants were not significant. One exception is that frail participants used protection such as face masks more often than non-frail participants in survey period 1. Another exception is that frail participants reported significantly more physical contacts than non-frail participants in both survey periods

The location where contacts take place also differed by frailty status and survey period. Frail participants had a similar fraction of contacts at home in both survey periods, and always more than non-frail participants (Fig. 5). In survey period 2, non-frail participants had especially more contacts at leisure activities. The fraction of repeated community contacts, i.e. persons who are not a member of the household that are contacted more than once a week, did not differ between frail or non-frail persons. Persons who lived alone however, did have relatively more repeated contacts than persons who lived in a multi-person household (Suppl. S5).

Discussion

In this survey, we studied how the contact behaviour of persons of 70 years and older in the Netherlands changed during periods with strict and moderate COVID-19 measures in 2021, and how these changes differed for frail and non-frail persons. Both frail and non-frail persons had more community contacts in October 2021 than in April 2021. During both survey periods, non-frail persons had more community contacts than frail persons. The two survey periods differed

in timing (spring vs autumn). As results of a contact survey in 2016-2017 [22] showed little effect of timing [3], the differences found between the two survey periods cannot be attributed to a seasonal effect. They are most probably caused by the difference in COVID-19 measures (stringent vs moderate) and the risk perception at that time.

The overall response rate of 15% is low because of at least two possible reasons. First, the returned questionnaires were unmarked by design which meant that it was not possible to send reminders to non-responders. Second, participation required considerable effort to keep a contact diary for a full week, which makes it difficult for invitees with cognitive issues or difficulties with reading and writing to participate. This may have led to a selection bias for non-frail participants, but as the frailty distribution by age and gender of the study population (Fig. 1A) agrees with results reported for the Tilburg Frailty Indicator of community-dwelling elderly [35], we believe that the study population largely represents the community-dwelling elderly population.

Compared to the Dutch 70+ population, participants with a migration background are underrepresented. As their frailty status distribution and number of contacts do not differ from the other participants, we have included them in the analyses. The participants in long-term care facilities were excluded from the analysis. They were more frail (8 out of 10) and had significantly more contacts than the community-dwelling study population.

Of the two survey periods, the second most resembles a situation without any COVID-19 measures. The 3.9 (0 - 15) contacts per day (mean and 95% interval) in this second survey period is lower than the 7.3 (0 - 24) and 7.1 (0 - 19) contacts per day found for 70+ participants in two previous studies in 2006-2007 [21] and 2016-2017 [22], respectively. Although the study populations and questionnaires are different, some factors could explain this discrepancy. First, having to fill out the diary every day causes a fatigue effect (Suppl S3). Correcting for this effect would increase the average number of contacts by 13%. A second explanation would be that due to COVID-19 information campaigns, participants better understand what constitutes a contact that could possibly lead to transmission, and filled out the diary more conservatively compared to pre-pandemic contact surveys. A final explanation is that participants did not revert to pre-pandemic behaviour.

During both study periods, two other contact surveys were conducted in the general population. The PiCo survey was held three times per year in a representative sample of the Dutch population [3,36]. The CoMix survey was held every two weeks in a selected internet panel [37,38]. The 70+ participants in the PiCo and CoMix surveys reported 2.3 (0 - 8) (mean and 95% interval) and 2.5 (0 - 11) contacts per day around survey period 1, and 5.1 (0 - 31) and 5.1 (0 - 24) contacts per day around survey period 2. While these studies agree, they find a larger difference between the survey periods than this study: 2.8 (0 - 8) and 3.9 (0 - 15) contacts per day in survey period 1 and 2 respectively. This could be an effect of differences in study setup, questionnaire, study population and fatigue effect. For instance, the 70+ participants in a randomly sampled population are on average younger than in this study where older age groups are oversampled.

In previous studies [39,40], it was observed that the number of contacts of elderly decreases with age. The results of this study show that in survey period 2 - that not fully but most resembles a normal situation - the number of contacts only slightly decreased with age (Fig. 2). Because frail persons have on average less contacts than non-frail persons, the decrease by age as observed in previous studies, is merely caused by persons transitioning from non-frail to frail status as they grow older. Especially for women, frailty is a better predicator for number of contacts than age. In survey period 1 with more stringent COVID-19 measures, the number of contacts of non-frail persons did decrease with age. These older non-frail persons interact mainly with persons of similar age (Fig. 3) who are increasingly frail (Fig. 1A). As a consequence, their behaviour change indirectly protected their frail peers. Younger non-frail persons did not decrease their contacts as much possibly because they did not interact with frail persons as much, and frail persons themselves all decreased their contacts probably to protect themselves.

The results of this study reveal how social distancing measures affected the contact behaviour of frail and non-frail persons of 70 years and older during the COVID-19 pandemic in the Netherlands, with the largest effect on the oldest non-frail participants. These results can be useful in different ways. Frailty questions could be included in contact surveys for the general population, as frailty is an additional indicator for the number of contacts. Stratifying infectious disease models by frailty could increase knowledge on how frail and non-frail persons are affected under different control scenarios, although it would first be required to know how frail and non-frail persons mix. These results can also be instrumental in public health policy, for instance in shaping information campaigns on social distancing measures. As the population in many countries ages rapidly, it is becoming ever more important to take frailty differences of elderly into account to be prepared for future pandemics.

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Ethical statement

The Medical Research Ethics Committee (MREC) NedMec confirmed that the Medical Research Involving Human Subjects Act (WMO) does not apply to the SCONE (Studying Contacts of Elderly) study (research protocol number 23-051/DB). Therefore an official approval of this study by the MREC NedMec is not required under the WMO.

Participants were informed that by returning the original questionnaire to RIVM, they were consenting to participate in the study. They were also informed that the data and results would

be made publicly available in an anonymous way, so that individual participants could not be (re)identified.

The initial processing of personal data by RIVM is lawful since it is necessary for the performance of a task carried out in the public interest (article 6, paragraph 1, under e, of the GDPR).

In the context of making the data and results publicly available for scientific or statistical purposes, the principle of data minimisation is being respected. Whenever possible, the data is minimised by aggregating open, easily identifiable and unnecessary records (article 5, paragraph 1, under b and article 89, paragraph 1, of the GDPR).

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Table 1: Number of participants, stratified by survey round, age group, gender, country of birth, frailty, household size and education level, for all 730 participants.

variable	value	n (%)
Survey period	1 (April 2021)	345 (47.3)
	2 (October 2021)	385 (52.7)
Participant age group	70-74	142 (19.5)
	75-79	137 (18.8)
	80-84	155 (21.2)
	85-89	168 (23.0)
	90+	128 (17.5)
Participant gender	Female	319 (43.7)
	Male	411 (56.3)
Country of birth	Netherlands	694 (95.1)
	Other country	34 (4.7)
	(Missing)	2 (0.3)
Frailty (GFI)	0-1 (non-frail)	253 (34.7)
	2-3 (non-frail)	218 (29.9)
	4-5 (frail)	144 (19.7)
	6-7 (frail)	69 (9.5)
	8+ (frail)	42 (5.8)
	(Missing)	4 (0.5)
Household size	1	285 (39.0)
	2	424 (58.1)
	3+	8 (1.1)
	Not applicable	10 (1.4)
	(Missing)	3 (0.4)
Education level	Primary or no education	94 (12.9)

variable	value	n (%)
	Secondary education (3 or 4 years)	303 (41.5)
	Secondary education (5 or 6 years)	144 (19.7)
	Higher education	176 (24.1)
	(Missing)	13 (1.8)

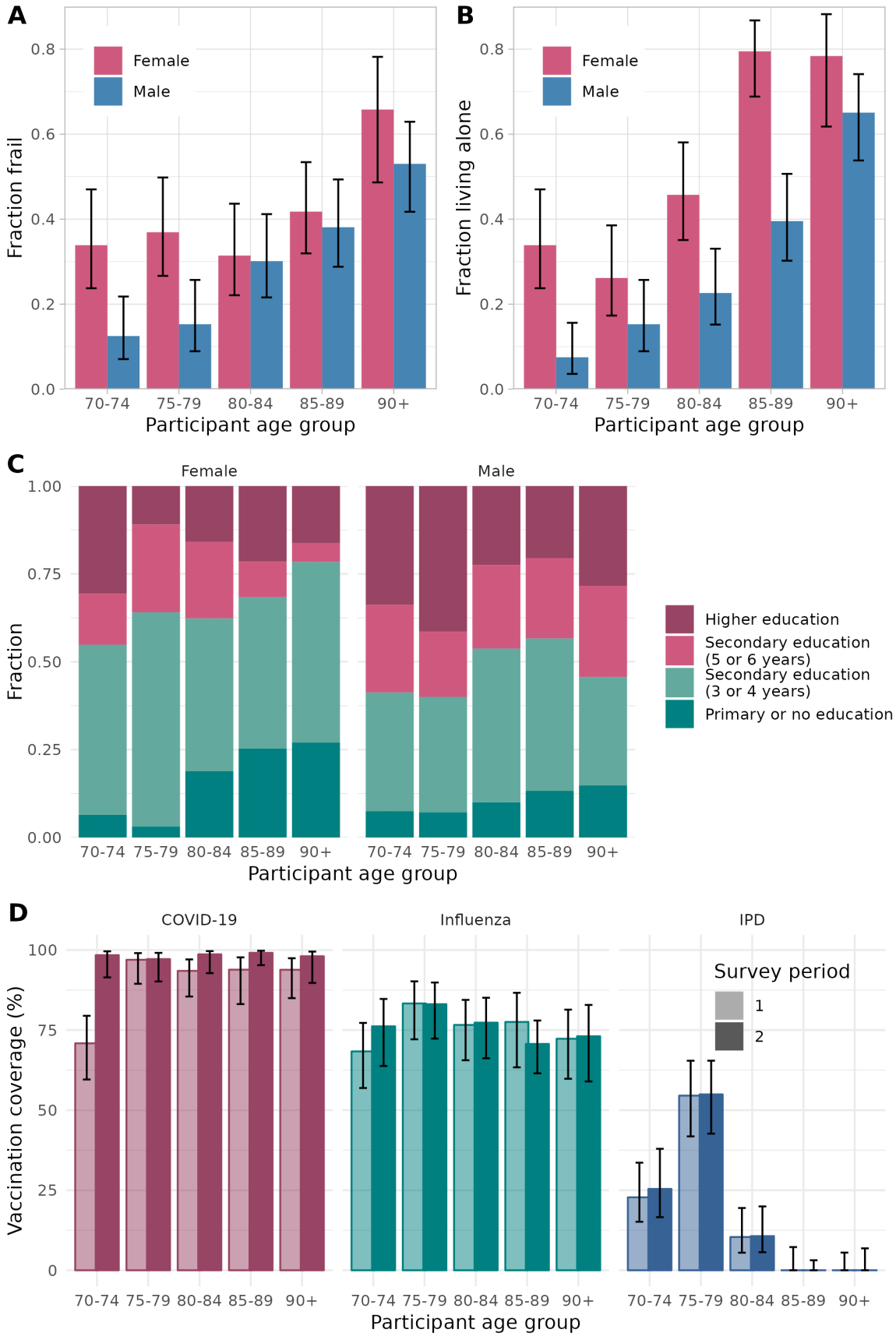

Figure 1: Participant characteristics of the study population consisting of 720 community-dwelling participants. (A) Fraction of frail participants by age group and gender. (B) Fraction of participants living alone by age group and gender. (C) Distribution of education level of participants by age group and gender. (D) Vaccination coverage against COVID-19, influenza and invasive pneumococcal disease (IPD) by age group and survey round.

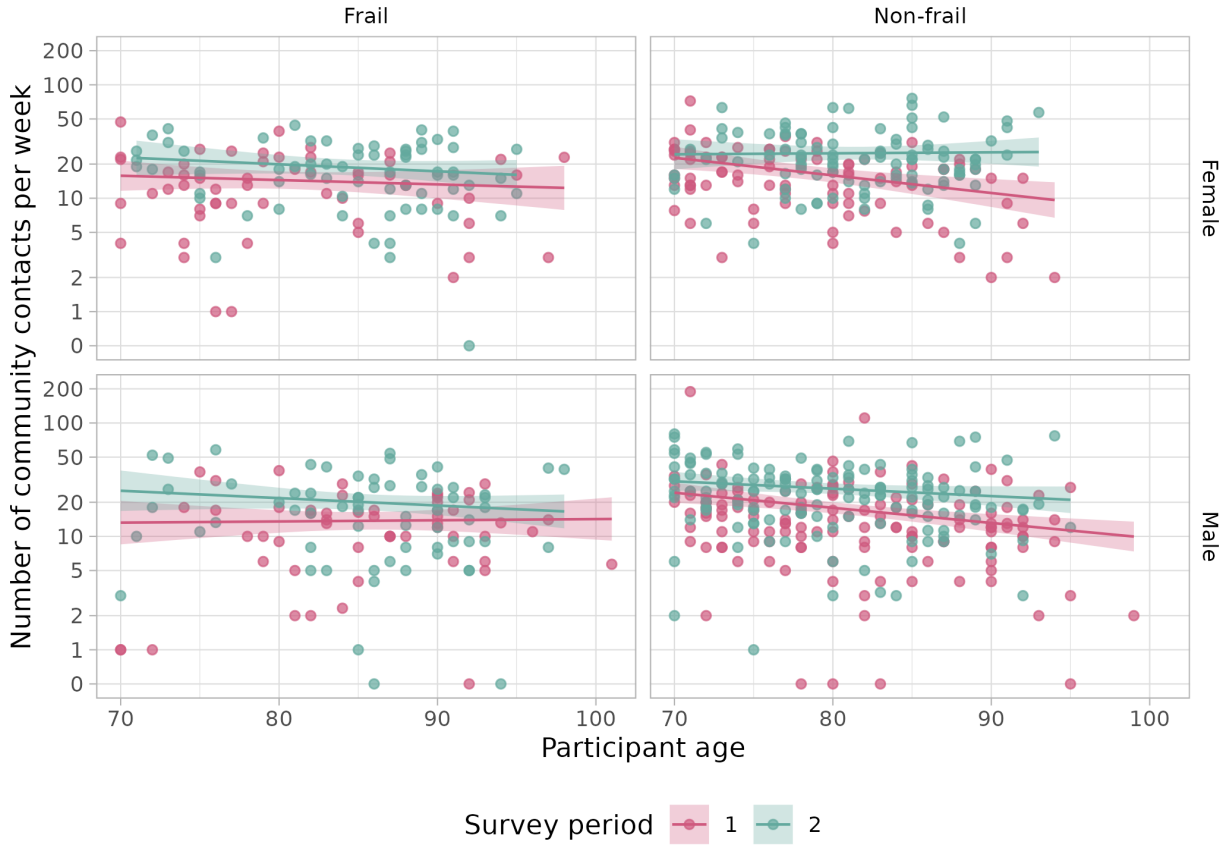

Figure 2: Weekly number of community contacts (i.e. persons contacted outside the household) per participant by age in survey periods 1 and 2. Plots show the data (one point for each participant) and model results (mean as solid line and 95% confidence interval as shaded area) by frailty (columns) and gender (rows).

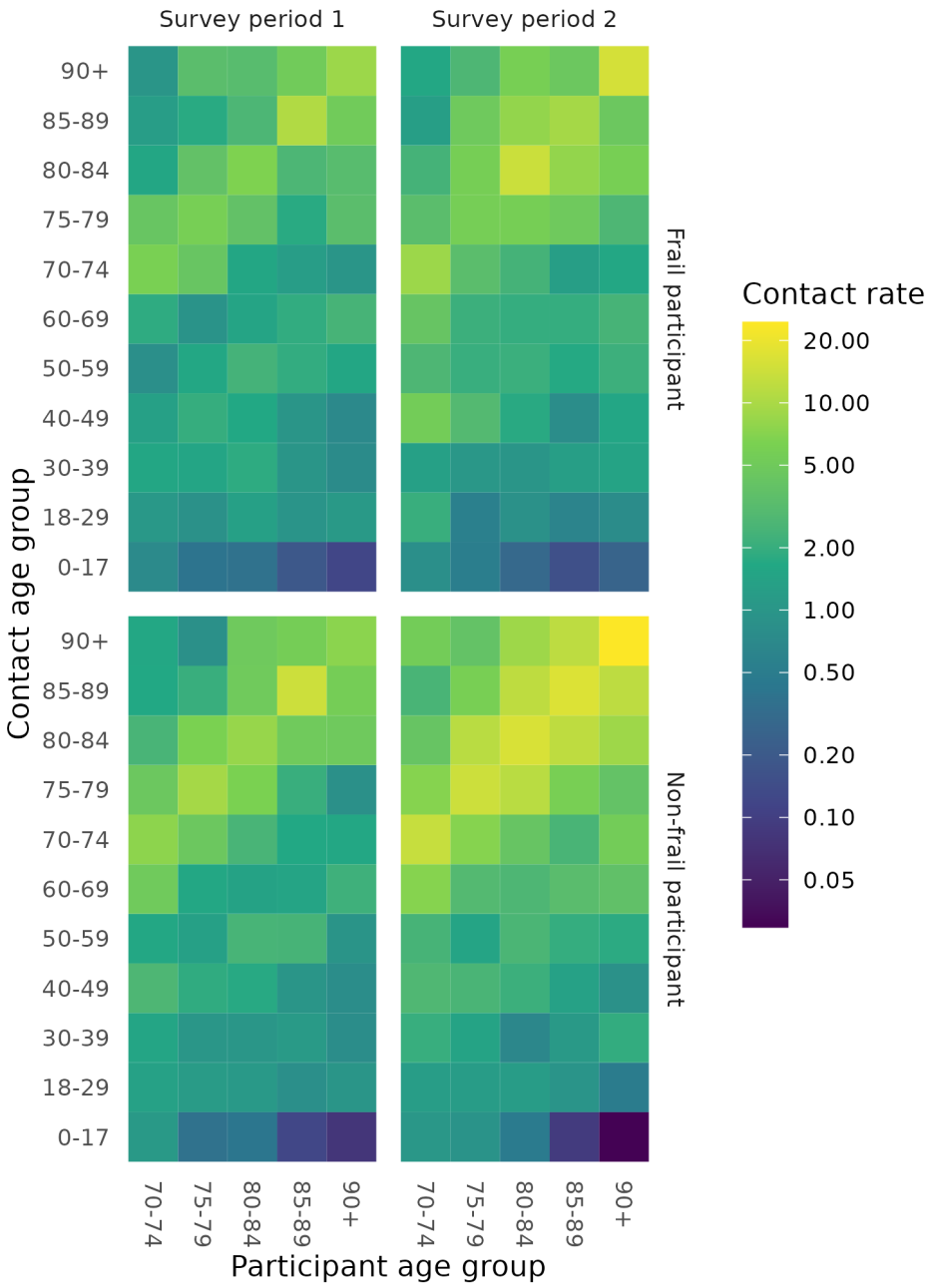

Figure 3: Contact matrices showing age mixing patterns for frail and non-frail participants in survey periods 1 and 2. The contact rate can be interpreted as the average number of community contacts (i.e. persons contacted outside the household) per participant per week, if the population were uniformly distributed over the age groups.

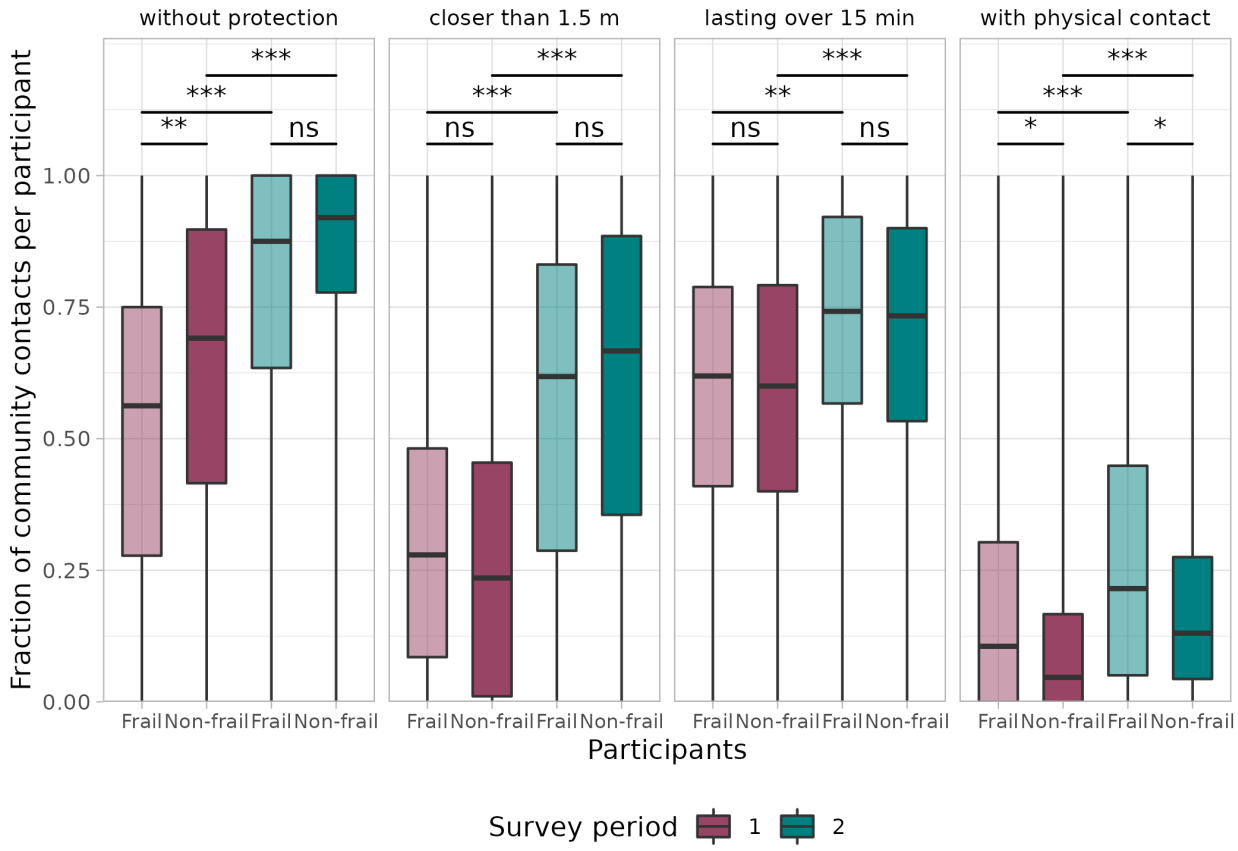

*Figure 4: Fraction of community contacts (i.e. persons contacted outside the household) per participant for four risk behaviour factors: protection, distance, duration and physicality of the contact. Distinction is made between frailty of participants (transparency) and survey period (color). The whiskers of the boxplots extend to the minimum and maximum values. Significance levels are denoted by *** (p-value < 0.001), ** (p-value < 0.01), * (p-value < 0.05), and ns (not significant).*

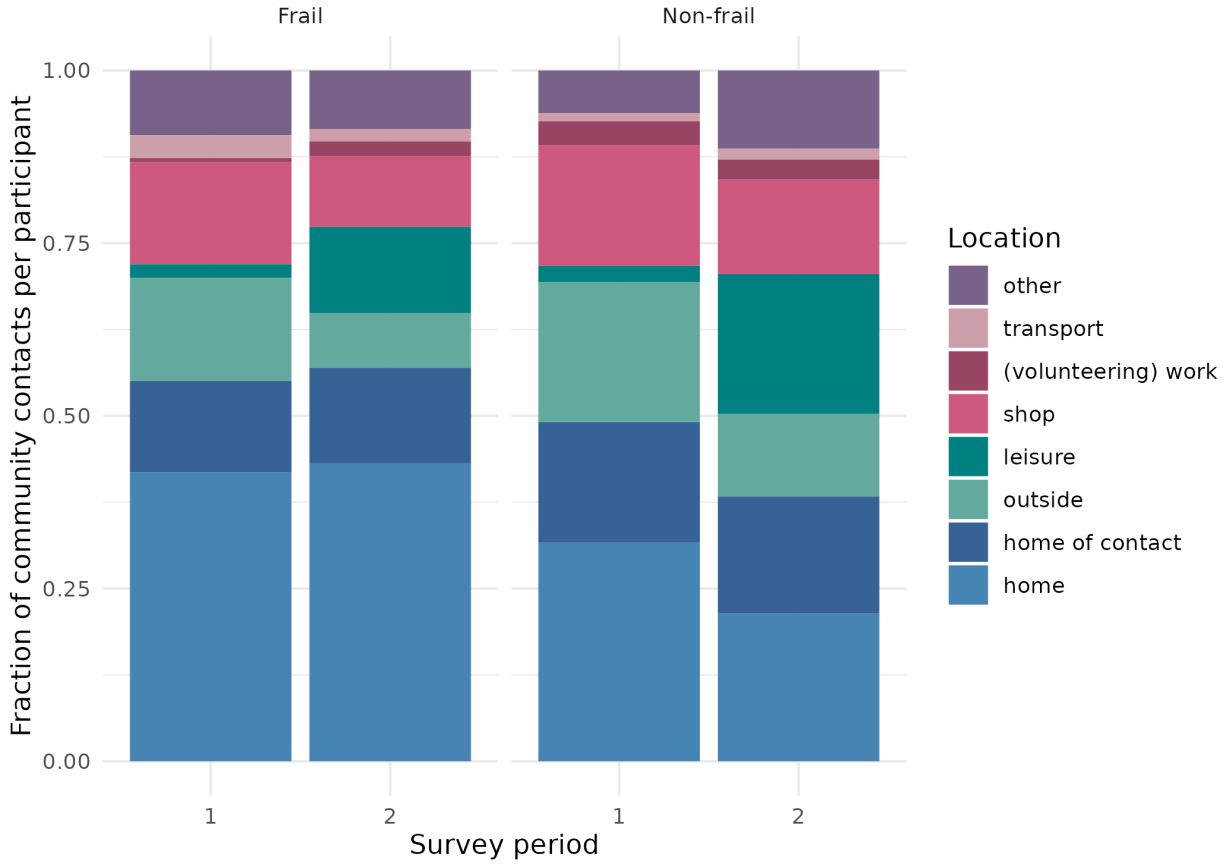

Figure 5: Fraction of community contacts (i.e. persons contacted outside the household) per participant by location for frail and non-frail participants in survey periods 1 and 2.