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Social contacts and mixing patterns in rural Gambia

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Abstract

Background Close contact between an infectious and susceptible person is an important factor in respiratory disease transmission. Information on social contacts and mixing patterns in a population is crucial to understanding transmission patterns and informing transmission models of respiratory infections. Although West Africa has one of the highest burdens of respiratory infections, there is a lack of data on interpersonal contact and mixing patterns in this region.

Methods Between January and November 2022, we conducted a cross-sectional, social contact survey within the population of the Central and Upper River Regions of The Gambia. Selected participants completed a questionnaire about their travel history and social contacts, detailing the number, intensity, location, frequency, duration, and age of contacts. We calculated age-standardized contact matrices to determine contact patterns in the population.

Results Overall, individuals made an average of 12.7 (95% CI: 12.4–13.0) contacts per day. Contact patterns were mostly age-assortative and 84.5% of all contacts were physical. School-aged children (5–14 years) had the highest mean number of physical contacts (11.3, 95% CI: 10.9–11.8) while the < 1-year age group had the fewest contacts (9.4, 95% CI: 9.1–9.8). A large proportion of contacts (78%) occurred at home. Daily number of contacts increased with household size. While we did not observe any effect of gender on contact patterns, there were seasonal variations in contact type. Non-physical contacts were higher during the dry season compared to the rainy season. In contrast, there were more physical contacts in the rainy season compared to the dry season.

Conclusions In rural Gambia, social contact patterns were primarily driven by household mixing. Most contacts were physical and mostly age-assortative, particularly among school-aged children. Our data can improve infectious disease transmission models of respiratory pathogens in high-transmission settings, which are valuable for optimizing the delivery of different interventions.

Keywords Social contacts, Mixing patterns, Pathogen transmission, Infectious diseases, The Gambia

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Background

Respiratory tract infections (RTIs) are a leading cause of global morbidity and mortality [1]. In 2019, before the COVID-19 pandemic, just under 500 million people were infected with respiratory tract infections with approximately 2.4 million associated deaths worldwide. The highest burden of RTIs was observed in children aged under five years, those above 70 years of age, and individuals living in vulnerable settings in South Asia and sub-Saharan Africa (SSA). About 90% of these deaths occurred in low and middle-income countries (LMICs) [2, 3]. RTIs are transmitted person to person through direct contact, indirect contact via fomites, aerosols, and respiratory droplets [4]. Social contacts facilitate transmission between infected and susceptible individuals and mixing patterns between subpopulations, such as different age groups, and their relevance to the transmission of respiratory infections are well-described [5–8]. Social contact refers to the number of interactions between individuals, and studies have been conducted to quantify and characterize contact mixing patterns.

Different approaches have been used to measure social contacts, such as retrospective self-reports through interviews or surveys, and the use of paper or digital diaries for prospective contact reporting [5, 9]. Relying on questionnaires and self-reporting techniques may present several challenges, including the risk of recall bias leading to underreporting, and reporting fatigue, particularly for contacts that occur outside the household [4, 10–12]. Recent contact studies have utilized proximity-detecting wearable sensors [13], and video analysis [14] to measure contact in different settings, including surveys that report on group contacts. The advantages and limitations of these methods have been described previously [15].

Information on social contacts, especially close and physical contact between infectious and susceptible individuals, are important in understanding the dynamics of infectious disease transmission. Social contact data are a key parameter in the accurate modelling of infectious disease transmission, which can be used to project the effect of interventions such as quarantine, lockdown, or travel restrictions against infectious diseases, and to predict transmission patterns of infectious diseases of pandemic potential such as the COVID-19, severe acute respiratory syndrome (SARS) and influenza [4, 16–18]. Contact data are also essential in modelling the spread of viral hemorrhagic fever pathogens such as Ebola and Marburg [19].

Most social contact studies have been conducted in high and middle-income countries [20, 21]. Although recent modelled estimates show that SSA has one of the highest burdens of respiratory disease globally [22], recent systematic reviews of social contact surveys to inform transmission models of close contact infections demonstrated a dearth of data from Africa. Only seven studies from SSA were eligible for inclusion [21, 23]. Currently, only twelve social contact studies have been reported from SSA with only one from West Africa [8, 10, 24–32]. We report the results of a large-scale, population-based social contact study in The Gambia. These social contact data will provide important inputs into modelling respiratory infection dynamics in similar settings.

Methods

Study setting and population

The Gambia is a small country in West Africa with a population of 2.4 million. The Central River Region (CRR) and Upper River Region (URR) are in the eastern part of The Gambia (Fig. 1). The Medical Research Unit The Gambia at the London School of Hygiene & Tropical Medicine operates the Basse and Fuladu West Health and Demographic Surveillance Systems (BHDSS and FWHDSS) in URR and CRR respectively. In 2022, the BHDSS population was 206,429 (224 villages) with 116,299 in the FWHDSS (217 villages). Females make up 53% of the population and approximately 15% of the population is aged < 5 years. The annual birth cohort of BHDSS and FWHDSS is approximately 8,000. Geographically, the BHDSS and FWHDSS cover approximately 2558km^2 and lie between latitude 13°30'16.1' and 13°30'27.0' north and longitude 15°00'58.3' and 13°51'40.4' west. There are two main ethno-linguistic groups, Fula and Serahule. The region is characterized by Guinea Savannah vegetation with two distinct seasons: a dry and hot season (November to May), and a rainy season (June to October). The average annual rainfall is approximately 876 millimetres with the heaviest rains in August. Minimum temperatures range between 15 and 25 °C while the maximum temperature ranges between 32 and 42 °C [33]. The main source of livelihood is subsistence agriculture. Groups of families live together in the same dwelling unit called a compound. Compounds, with an average size of 38 persons are headed by one adult male or female. The disease burden of the region is characteristic of many rural settings in SSA with half of deaths amongst children under five years of age occurring at home and going unreported. There are two main hospitals, two private clinics and several health centres and pharmacy shops in the surveillance area [34, 35]. The educational system in the Gambia comprises three years of early childhood education (ages 3–6 years); six years of lower basic education (ages 7–12 years); three years of upper basic education (ages 13–15 years); and three years of upper secondary education (ages 16–19). Many schools, particularly in rural areas, operate on a shift system where some students attend morning classes while others go in the afternoon. Most schools in the study

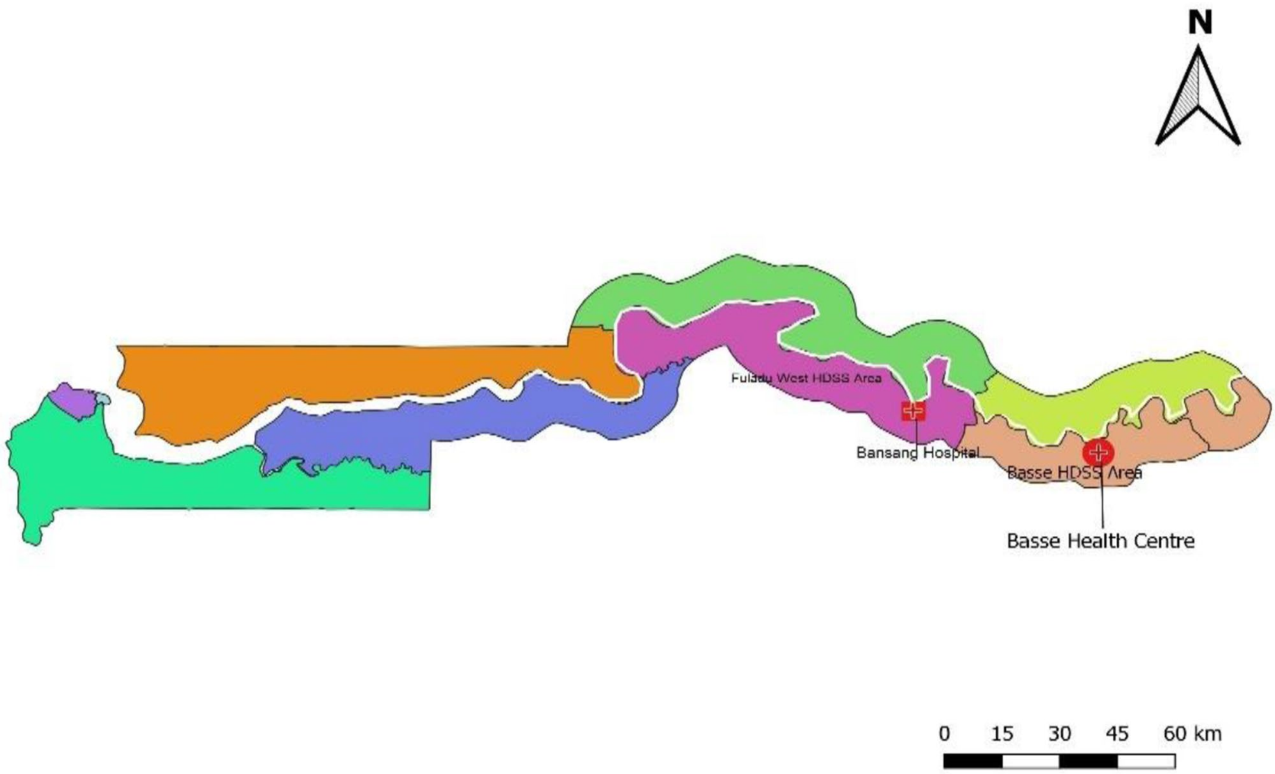

Fig. 1 Map of the gambia highlighting the fuladu west and basse health and demographic surveillance systems in central and upper river regions

area, like many across The Gambia, are mixed-gender, with both genders in the same classroom [12, 36].

Study design

This study was nested within the Pneumococcal Vaccine Schedules (PVS) trial which is ongoing in CRR and URR. PVS (trial number: ISRCTN15056916||http://www.isrctn.org/. Registered on 15 November 2018) is a non-inferiority, cluster-randomized trial of two different delivery schedules of a pneumococcal conjugate vaccine (PCV) [37]. The primary endpoint of the trial is nasopharyngeal carriage of vaccine-type pneumococci in children aged 2 weeks – 59 months with clinical pneumonia. Infants in the study area received either three doses of PCV given at ages 6, 10, and 14 weeks (the standard schedule) or two doses given at 6 weeks and 9 months of age (an alternate schedule) in 68 randomized geographically separate clusters of villages. Between January and November 2022, three years after the commencement of PVS, we conducted a cross-sectional social contact survey in parallel with a pneumococcal carriage study among residents in CRR and URR. We report here the results of the survey of social contacts in the study area.

Participant selection and sampling

A sampling frame including residents of all ages was obtained from the BHDSS and FWHDSS. A Demographic Surveillance Systems (DSS) resident was defined as an individual who had been resident for more than four months in the area covered by the DSS, as confirmed by DSS records or a household visit with a report from the household or compound head. For infants, residency was defined as being born to, or cared for, by a parent/guardian who was resident for greater than four months or who intended to be resident for greater than four months, with verification by DSS records or a household visit with the report of the household or compound head. We used the DSS to determine cluster, village, compound, and household population sizes, and as a reference for the members of a household. A household was defined as a group of people living together (related or unrelated) who share or eat from the same cooking pot. There are 68 geographic clusters and 441 villages within the BHDSS and FWHDSS. Three-stage sampling, using probability proportional to size, was used to randomly select two villages within each of the 68 clusters, and then two compounds were randomly selected per village and six individuals were randomly selected per compound. A compound consists of several different households. A household includes other members within the same compound who share or eat from the same cooking pot. Within each compound, one household was randomly selected and within selected households, six individuals stratified by age group (0-11 months, 12-23 months, 24-59 months, 5-14 years, 15–44 years, and ≥45 years) were randomly selected. If a participant in a particular age group was unavailable, or the proportion was inadequate in the selected household, we selected the required participant from another randomized household in the compound. This procedure was repeated until the required number of participants was reached in the selected compound. Individuals not listed as residents within a selected compound were considered eligible if confirmed by the head of household as a resident in the past 4 months. We over-sampled young children to enable more precise estimates of contacts in this age group who are considered primary drivers of pneumococcal disease transmission.

Sample size estimation

A sample size of 1632 participants was selected for enrolment into the contact study. Recruiting a minimum of 1632 participants enabled us to detect an absolute difference of one mean contact per day between age groups, with a 5% significance level, and 90% power. This sample size calculation was based on a social contact survey conducted in rural Uganda [8].

Data collection

Field workers were trained for two weeks using a modification of the social contact questionnaire [see Additional file 1] used in a contact survey conducted in rural Uganda [8]. Initially, community sensitization meetings were held in the 68 clusters at which trained study staff who were fluent in the local languages provided information on the study and answered questions. Trained field workers made a minimum of two visits to selected households. During the first visit, trained field staff explained the nature of the study to the potential participants, obtained written informed consent from those who agreed to join the survey, discussed details of the social contact questionnaires with them, and primed them on making mental notes of their contacts throughout the next day (a 24-hour period). Parents or guardians from the community provided consent for themselves and on behalf of child participants (age < 18 years). Child participants aged 12–17 years also provided assent. On the second visit, which took place 48 hours after the first visit, the field worker took the participant through their previous day's activities (i.e., morning, afternoon, and evening activities for the past 24 hours). The field worker first asked for the initials and nicknames (if they had one) of the contacts, then went through all listed contacts and asked for details such as gender and age of contactee, type of contact (physical vs non-physical), location (home, work, public transport, leisure, etc.), duration of the contact (< 15mins, 15mins – <1hr, 1 h – <2 h, 2 h-<4 h, ≥4 h) and the frequency of contact (daily, once or twice per week, once or twice per month, less than monthly, or first time meeting). The DSS was used to determine the ages of household member contacts. Participants provided estimated ages for non-household contacts. A contact (contactee) was defined as an individual whom the participant met in person during the 24 hours before waking up on the day being surveyed, with whom the participant had at least a short conversation and with whom they had either (i) "physical contact" (any sort of skin-to-skin contact e.g. a handshake, embracing, kissing, sleeping on the same bed, etc), or (ii) "Non-physical contact" (did not touch the person but exchanged at least a few words, face-to-face within two metres)" [38]. If a contact was both physical and non-physical, contact was recorded as physical. Participants also provided estimates of the number of 'casual contacts' they had based on pre-determined ranges (< 10, 10–19, 20–29, ≥ 30). We defined 'casual contacts' as brief interactions lasting less than five minutes [38]. For children < 10 years old, a parent or guardian completed the survey questionnaires on their behalf. In most instances, parents and caregivers assisted older children in reporting their contacts. Data were collected electronically using a customized Microsoft Access application.

Statistical analysis

Descriptive analyses of the distribution of socio-demographic factors including occupation, interview day, season, household size and contact information using simple frequencies and proportions for categorical variables and means, and medians for continuous variables were performed. The proportions of physical and non-physical contacts by contact frequency, duration, location, and relationship of contact to the participant were measured. Due to the oversampling in the younger age group, we applied post-stratification weights to calculate representative population-level median and mean estimates of contact events for parameters including age, gender, occupation, interview day, season and household size by contact type (physical and non-physical), and contact location. The 95% confidence intervals (95% CI) of the point estimates were presented. The frequency and duration of individual travel outside their village of residence were estimated. Age-stratified contact matrices and per capita contact rates (the probability that any two individuals would come into contact on a given day) were calculated using the *socialmixr* package in *R*, using post-stratification weights on age, gender, and weekday, and adjusted for reciprocity of contacts. More details about the post-stratification and adjustment for reciprocity are provided in the [see Additional file 2] [39]. As previously reported [12], we observed social contacts within schools and assessed the accuracy of proxy-reported versus observed physical contact data among a subset of school-going participants enrolled in this study. All central estimates are weighted means, medians, or proportions except for the frequency and distribution of participants and contacts ages as shown in the histograms [see Fig. 2]. The observation period for the school-based contact survey lasted only 2 h (one hour in the classroom and another hour during the break period) and so does not capture a full school-day contact. Most of the school-based contact observations (> 80%) were not collected on the same day that the proxies reported contacts at school. A sensitivity analysis was performed to determine if substituting the reported school-based contacts with the observed contacts affected the population inter-contact pattern matrix [see Additional files 3 and 4]. Stata version 18.0 (StataCorp LLC, TX, USA) [40] and R version 4.2.0 [41] were used for all data management and analyses. This study is reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [See Additional file 5].

Ethics approval and consent to participate

The study was approved by the Gambia Government/MRC Joint Ethics Committee (ref: 28705) and by the LSHTM Ethics Committee (ref: 28705). Written, informed consent to participate was obtained from all enrolled participants.

Results

Characteristics of the study participants

A total of 1638 participants from 611 households dwelling in 158 different compounds across 441 villages from 68 clusters were enrolled. Only one person declined consent. There were no missing data. The median age of the participants was four years (IQR: 1–25). The median household size was 33 members (IQR: 20–58). A third (33.5%) of the participants were below two years of age and there were slightly more females (54.5%) than males. Among the enrolled participants, 180 (25.4%) were farmers, 228 (32.1%) were students, and almost all contacts (98.1%) were reported on a weekday. Most contacts (66.4%) were recorded during the rainy season (Table 1).

Characteristics of contacts

A total of 19,819 contacts were reported. The weighted daily mean number of contacts was 12.7 (95% CI: 12.4–13.0). The median age of contacts was 16 years (IQR: 8–32). Those aged ≥ 45 years had the highest mean number of contacts (13.1, 95% CI: 12.5–13.6) while the < one-year-old age group had fewer contacts (11.0, 95% CI: 10.6–11.4). The average number of daily contacts was comparable among males (12.8, 95% CI: 12.3–13.3) and females (12.5, 95% CI: 12.2–12.9), relatively homogenous by occupation, increased with household size, and were slightly higher during the dry season (13.0, 95% CI:

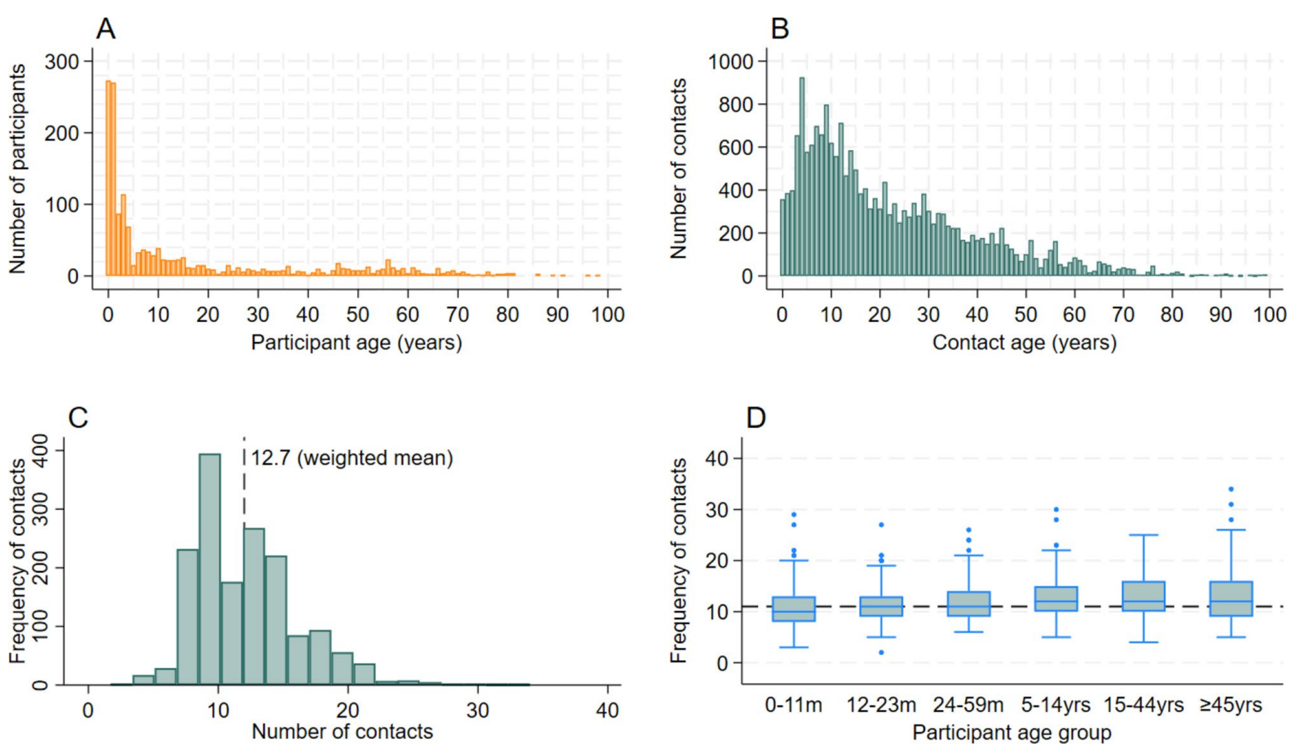

Fig. 2 The number and frequency distribution of participants and contacts. (**A**) The frequency distribution of participants, (**B**) The age frequency and distribution of contacts, (**C**) the distribution of the overall number of contacts (with weighted mean shown as a dashed line), (**D**) Boxplot showing the median (centre line) and interquartile range (IQR) of contact rates per age group per day, with mean (dashed line) contact rate per person per day

Table 1 Median and mean number of reported daily contacts by socio-demographic characteristics, contact type and contact location

Characteristics	[b]Number of participants (%)	Median[a] number of contacts (IQR)	Contact type[a]			Contact location[a]		
			Mean number of total contacts (95% CI)	Mean number of physical contacts (95% CI)	Mean number of non-physical (95% CI)	Mean number of contacts at home or another house (95% CI)	Mean number of contacts at school or work (95% CI)	Mean number of contacts at other settings (95% CI)
Overall	1638 (100)	12 (9–15)	12.7 (12.4–13.0)	10.6 (10.4–11.1)	2.0 (1.8–2.2)	11.3 (11.0–11.6)	0.5 (0.4–0.7)	0.8 (0.7–1.0)
Age								
0–11 months	277 (16.9)	10 (8–13)	11.0 (10.6–11.4)	9.4 (9.1–9.8)	1.5 (1.3–1.8)	10.7 (10.3–11.1)	0.0 (0.0–0.0)	0.3 (0.2–0.4)
12–23 months	271 (16.5)	11 (9–13)	11.1 (10.7–11.5)	10.0 (9.6–10.3)	1.0 (1.0–1.4)	11.0 (10.5–11.4)	0.0 (0.0–0.0)	0.2 (0.1–0.2)
24–59 months	272 (16.6)	11 (9–14)	11.7 (11.3–12.1)	10.3 (9.9–10.7)	1.0 (1.0–1.6)	11.2 (10.8–11.6)	0.2 (0.1–0.3)	0.3 (0.2–0.4)
5–14 years	279 (17.0)	12 (10–15)	12.9 (12.4–13.3)	11.3 (10.9–11.8)	1.5 (1.2–1.7)	11.4 (11.0–11.8)	0.9 (0.6–1.2)	0.5 (0.4–0.7)
15–44 years	269 (16.4)	12 (10–16)	12.8 (12.2–13.3)	10.4 (9.9–10.8)	2.3 (2.0–2.7)	11.3 (10.8–11.9)	0.5 (0.2–0.8)	1.0 (0.7–1.2)
45 + years	270 (16.5)	12 (9–16)	13.1 (12.5–13.6)	10.3 (9.9–10.8)	2.7 (2.3–3.1)	11.3 (10.8–11.8)	0.0 (0.0–0.1)	1.8 (1.4–2.1)
Gender								
Male	747 (45.6)	12 (10–15)	12.8 (12.3–13.3)	10.6 (10.1–11.0)	2.2 (1.9–2.5)	11.3 (10.8–11.8)	0.6 (0.3–0.9)	0.9 (0.7–1.1)
Female	891 (54.4)	12 (9–15)	12.5 (12.2–12.9)	10.6 (10.4–10.9)	1.8 (1.6–2.0)	11.3 (11.0–11.6)	0.4 (0.3–0.6)	0.8 (0.6–0.9)
[c]Occupation								
Farmer	180 (25.4)	11 (9–15)	12.3 (11.5–13.1)	9.9 (9.2–10.6)	2.3 (1.8–2.9)	11.0 (10.2–11.8)	0.1 (0.1–0.3)	1.2 (0.8–1.5)
Trader	13 (1.8)	15 (10–18)	14.2 (11.5–16.9)	12.1 (10.4–13.8)	2.1 (0.6–3.7)	10.2 (9.0–11.3)	2.8 (1.2–6.7)	1.3 (0.1–2.5)
Student	228 (32.1)	12 (12–13)	12.4 (11.4–13.3)	11.0 (9.3–12.6)	1.4 (0.1–3.0)	9.8 (7.6–11.9)	0.9 (0.1–2.0)	1.6 (0.3–2.9)
Housewife	239 (33.7)	12 (9–15)	12.5 (12.0–13.0)	10.4 (10.0–10.9)	2.0 (1.7–2.4)	11.5 (11.0–11.9)	0.1(0.0–0.2)	0.9 (0.7–1.2)
Others	50 (7.0)	15 (9–17)	14.4 (12.5–16.2)	10.5 (8.9–12.2)	3.8 (2.3–5.3)	11.4 (9.4–13.5)	0.9 (0.4–2.2)	2.0 (1.0–3.0)
Interview day								
Weekday (Mon-Fri)	1606 (98.1)	12 (9–15)	12.6 (12.3–12.9)	10.6 (10.4–10.9)	1.9 (1.8–2.1)	11.3 (11.1–11.6)	0.5 (0.3–0.7)	0.8 (0.7–0.9)
Weekend (Sat-Sun)	31 (1.9)	13 (11–16)	13.9 (11.9–15.9)	10.2 (8.4–11.9)	3.8 (2.1–5.4)	10.6 (9.1–12.1)	0.1 (0.0–0.3)	3.3 (1.5–5.1)
[d]Season								
Dry	551 (33.6)	12 (10–15)	13.0 (12.4–13.4)	9.8 (9.4–10.3)	3.0 (2.6–3.3)	10.8 (10.4–11.3)	0.8 (0.4–1.1)	1.3 (1.0–1.5)
Rainy	1087 (66.4)	12 (9–15)	12.5 (12.1–12.9)	11.0 (10.7–11.3)	1.5 (1.3–1.7)	11.5 (11.2–11.9)	0.4 (0.2–0.5)	0.6 (0.5–0.7)
[e]Household size								
1–9	85 (5.2)	11 (9–13)	11.9 (10.9–12.8)	9.6 (8.4–10.8)	2.3 (1.5–3.1)	10.4 (9.7–11.1)	0.4 (0.1–0.8)	0.7 (0.1–1.3)
10–19	421 (25.7)	11 (9–15)	11.9 (11.3–12.4)	10.1 (9.7–10.6)	1.7 (1.4–2.1)	10.6 (10.2–10.9)	0.2 (0.1–0.4)	0.6 (0.5–0.8)

Table 1 (continued)

Characteristics	[b]Number of participants (%)	Median[a] number of contacts (IQR)	Contact type[a]			Contact location[a]		
			Mean number of total contacts (95% CI)	Mean number of physical contacts (95% CI)	Mean number of non-physical (95% CI)	Mean number of contacts at home or another house (95% CI)	Mean number of contacts at school or work (95% CI)	Mean number of contacts at other settings (95% CI)
20–49	796 (48.6)	12 (10–15)	12.8 (12.4–13.2)	10.7 (10.4–11.0)	2.0 (1.8–2.3)	11.3 (11.0–11.5)	0.2 (0.1–0.3)	0.8 (0.6–0.9)
≥ 50	336 (20.5)	13 (10–17)	13.6 (12.9–14.4)	11.5 (10.9–12.0)	2.1 (1.7–2.6)	12.0 (11.6–12.4)	0.3 (0.1–0.4)	0.5 (0.3–0.7)

IQR – Interquartile range

95% CI – 95% Confidence Interval

[a] Central estimates are the weighted mean or median

[b] Percentages of sample distributions are not weighted

[c] Does not include child participants too young to attend school

[d]Season: Dry = November – May; Rainy = June – October

[e] Household sizes include individuals from the same compound who eat from the same cooking pot

Contacts made by young children (< 10 years) were reported by adults or caregivers acting as proxies

12.4–13.4) compared to the rainy season (12.5, 95% CI: 12.1–12.9). Most of the contacts occurred at home (78%), with persons whom participants meet daily or almost daily (84%), with household members (65%), and most contacts lasted longer than four hours (62%). Only 2% of reported contacts occurred at school or work. Less than 1% of reported contacts were made with persons whom participants had never met before (Figs. 2 and 3).

Intensity, frequency, location, relationship, and duration of contacts

Most contacts (84.5%) were physical, with an estimated 10.6 daily physical contacts. Those aged 5–14 years had the highest mean number of physical contacts (11.3, 95% CI: 10.9–11.8) while the < one-year age group had the lowest mean number of physical contacts (9.4, 95% CI: 9.1–9.8). Physical contacts were relatively higher among traders and in those living in a larger household size. There were no gender differences in the estimated daily mean number of physical contacts in the population. There was a marked difference in the contact type by season. Although most contacts made across seasons were physical, the proportion of non-physical contacts was higher during the dry season (mean 3.0, 95% CI: 2.6–3.3) compared to the rainy season (mean 1.5, 95% CI: 1.3–1.7). In contrast, there were more physical contacts made during the rainy season (mean 11.6, 95% CI: 10.7–11.3) compared to the dry season (mean 9.8, 95% CI: 9.4–10.3). Most physical contacts (92%) occurred at home or another house with very few contacts occurring at school, work, or other settings. Most contacts occurring outside home or work were higher among those aged 45 years or older, during the weekend, and in the dry season (Table 1). The majority of physical contact was made with a household member (70%), people whom the participant meets daily or almost daily (88%) and lasted at least four hours (66%). The highest number of non-physical contacts was reported among the older age group, particularly those aged 45 years and older. (Table 1; Fig. 3, and Additional file 6).

Travel history

We estimate that about a third of the residents travel at least once a week to villages < 5 km from their village of residence. Very few residents (4%) never travel outside their village of residence. Among the residents who travel < 5 km from their village of residence, we estimate that 70% spend at most two hours and approximately 5% spend at least a whole day on their travels. Of the residents who travel to places ≥ 5 km from their place of residence, 54% do so at least once a month, 42% spend half a day, and a quarter spend at least a whole day (Tables 2 and 3).

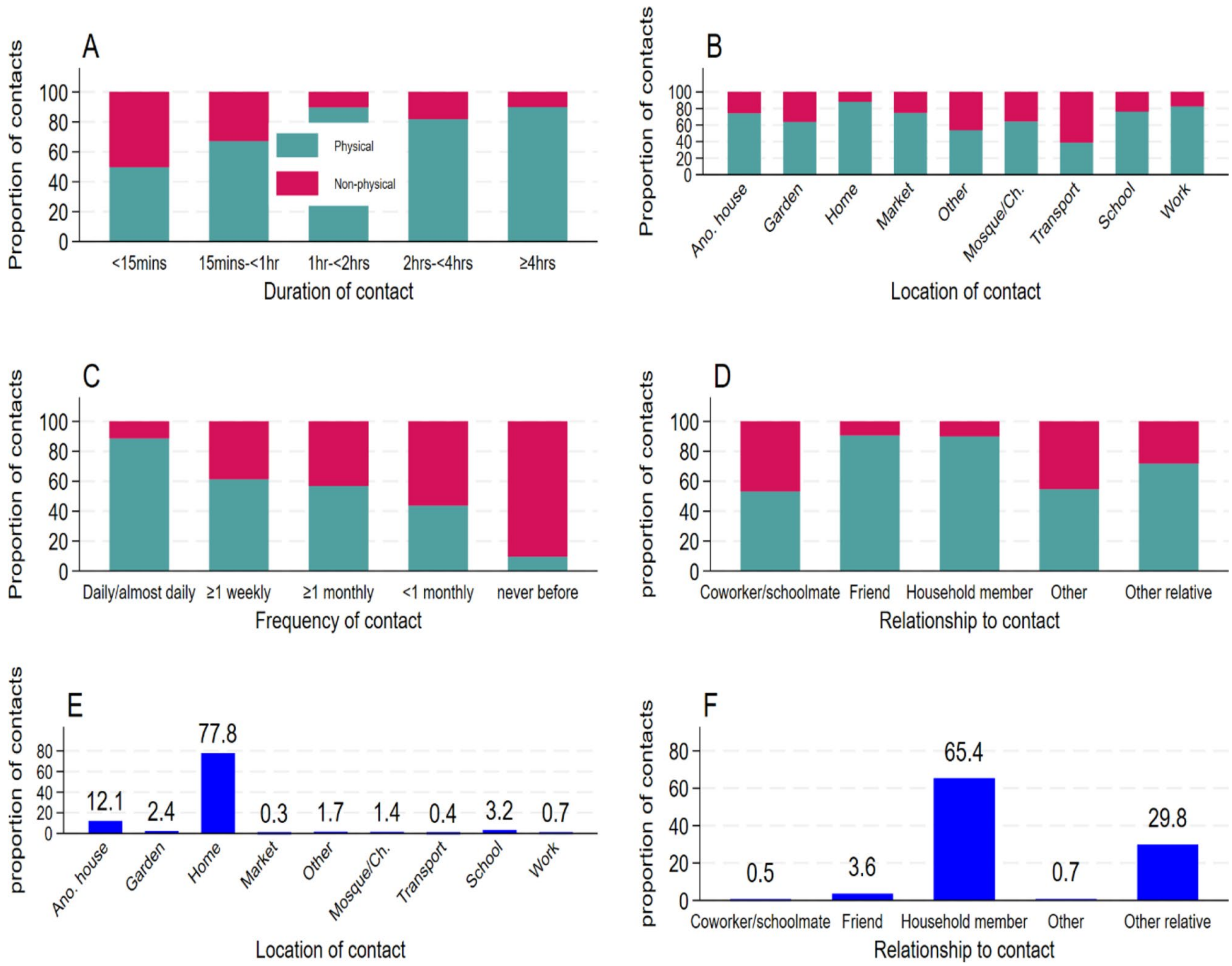

Fig. 3 The proportion of contacts by location, relationship to contact, and reported physical and non-physical contacts. The proportion of physical and non-physical by (**A**) duration, (**B**) location, (**C**) frequency, (**D**) relationship (**E**) proportions of contact by location (**F**) proportions of contact by relationship to contact

Table 2 Frequency of travel outside the village of residence

Travel distance	Most days of the week	At least once per week	At least once per month	Less than once a month	Never
< 5 km	13.6% (11.3 -16.4%)	27.3% (24.4 – 30.4%)	36.1% (32.8 – 39.6%)	18.8% (16.2 – 21.6%)	4% (3.1 – 5.5%)
≥ 5 km	5.4% (4.0 – 7.2%)	11.2% (9.0 – 13.8%)	54.0% (50.5 – 57.4%)	24.4% (21.5 – 27.5%)	5% (3.9 – 6.5%)

Estimates are the weighted proportion and corresponding 95% confidence interval

Table 3 Duration of stay when travelling outside the village of residence

Travel distance	< 1 h	1–2 h	Half a day	A whole day
< 5 km	43.0% (39.4 – 46.7%)	26.0% (22.9 – 29.3%)	26.2% (23.0 – 29.5%)	4.8% (3.5 – 6.6%)
≥ 5 km	9.7% (7.8 – 11.9%)	22.5% (19.6 – 25.8%)	42.2% (38.5 – 46.0%)	25.6% (22.4 – 29.0%)

Estimates are the weighted proportion and corresponding 95% confidence interval

Age-specific mixing patterns

Most contacts were made with children, and this is indicative of the youthful age structure of the population in the setting [34]. Social contacts were mostly age assortative as shown by the high contact rates on the diagonal of the matrix up to age group 25–30 years, indicating that individuals in the population were more likely to have contact with people of similar age groups (Fig. 4). The highest daily mean contact rates were noted among school-aged children (5–10 years) (Fig. 4 A). The highest mean contact rates were observed among children less than 20 years and the lowest within age group contacts were noted among those 50–55 years and 60–65 years old. Those aged > 30 years showed the highest

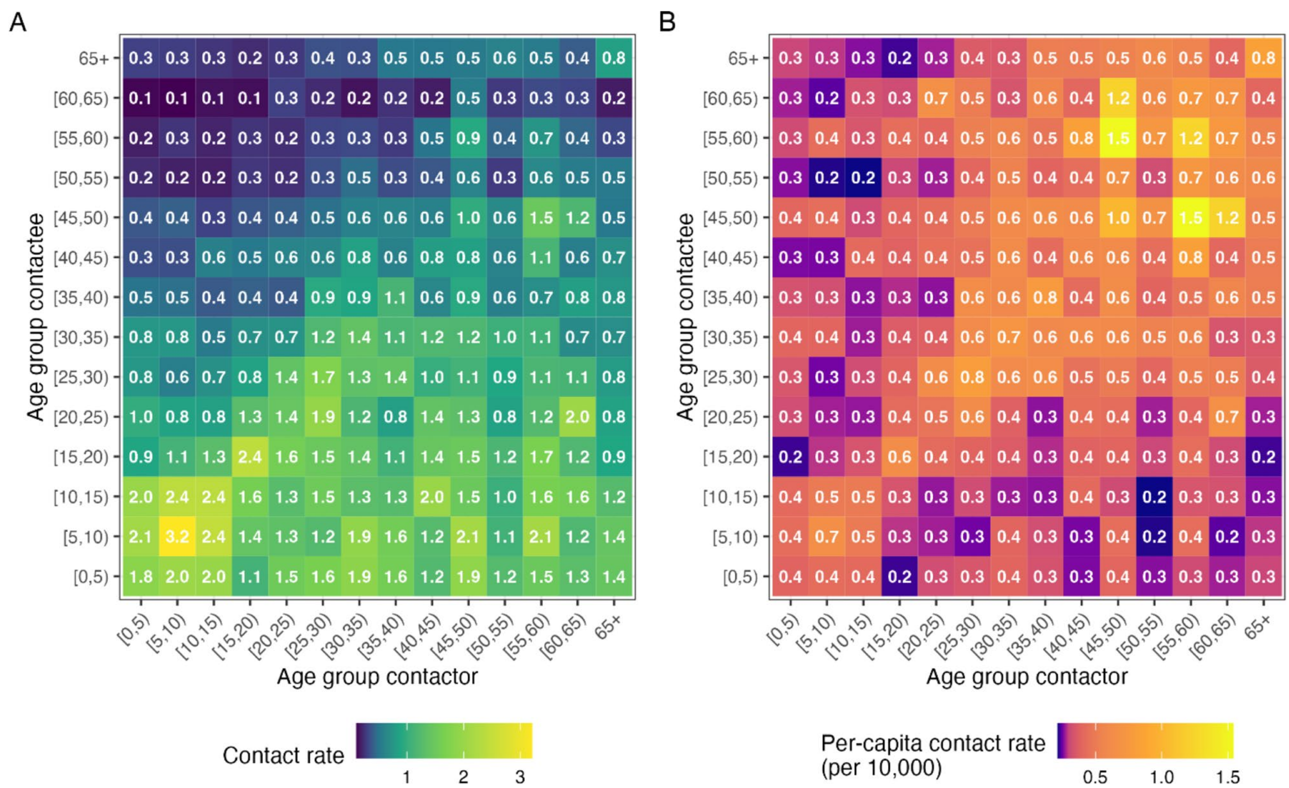

Fig. 4 Contact matrices. (**A**) the weighted mean number of daily contacts made by contactors with contactees of different age groups (**B**) age-specific weighted daily per-capita contact rates reported per 10,000 people (i.e. the rate at which any two individuals would come into contact on a given day). Parents and caregivers acted as proxies to estimate contacts of young children < 10 years. Both matrices are adjusted for the reciprocity of contacts

inter-generational contacts (Fig. 4 B). Our sensitivity analysis showed that substituting reported with observed school-based contacts increased the mean number of contacts from 12.7 to 16.0 (see Additional file 4). Due to the different methodologies, this increased number of contacts is most apparent in those 0–20 years old, with a weighted mean number of contacts of 18.2 in those aged < 20 years, and 12.7 in those aged > 20 years (see Additional files 3 and 4).

Gender-related contact pattern

Although there was no evidence of assortative contact by gender, a higher mean number of contacts was observed among same-gender interactions compared to different-gender contacts. Male gender contact patterns were slightly more pronounced than female mixing patterns, especially among the 10-20-year age group (Fig. 5).

Discussion

In this study, we examined the social contacts and mixing patterns relevant to the spread of respiratory infections in rural Gambia. We estimate that the daily mean number of contacts was relatively high, mostly physical and of long duration, and that contact patterns were mostly age-assortative, particularly among school-going children, and mainly influenced by intra-household mixing. Overall, on average, individuals made 12.7 (95% CI: 12.4–13.0) contacts per day. This finding is comparable to studies in Malawi [31], Somaliland [25], and Zimbabwe [30] but considerably lower compared to the 19.7 contacts reported in Senegal [32], 17.7 in Kenya [10], and 15.6 contacts in South Africa [42]. However, on average, individuals in our study reported a further nine "casual contacts", which were not added to our contact counts as casual contacts were deemed less relevant for the transmission of respiratory infections [43]. In addition to the setting and local context, the exclusion of "casual contacts" from our contact count may explain the difference between the average reported contacts in our study and the studies that recorded higher contacts.

Our results show that contact patterns were highly physical. School-aged children (5–14 years) had the highest mean number of physical contacts (11.3, 95% CI: 10.9–11.8) while the < one-year age group had fewer physical contacts (9.4, 95% CI: 9.1–9.8). To our knowledge, the observed 84.5% of all contacts being physical is the highest percentage of physical contact in the literature. The highest percentage of physical contacts recorded previously in the literature was 84.0%, observed in a survey of young children and their caregivers in Fiji [7, 21]. We observed that most of the physical contacts occurred at home, with household members, lasted at

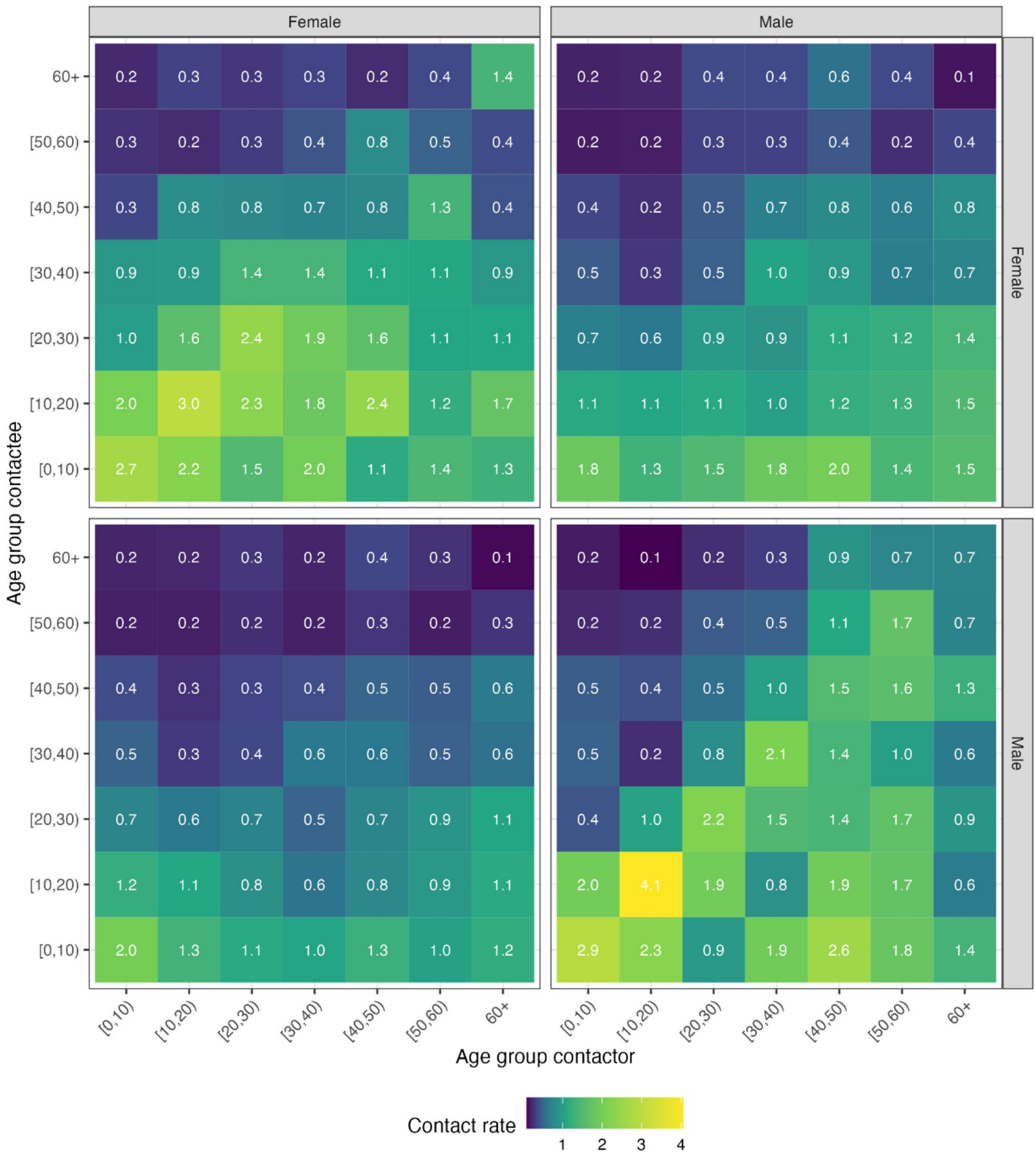

Fig. 5 Contact matrices by gender mix. This shows the weighted mean number of daily contacts made by contactors of different gender and age groups with contactees of certain gender and age groups. Facet columns show the gender of the contactor, while facet rows show the gender of their contactees

least four hours and was highest among school-aged children aged 5–14 years. We found that contacts increased with increasing household size. Our finding is consistent with studies from Africa conducted in similar settings in Malawi [31], southwest Uganda [38], and in Kenya [10]. This finding was not surprising as it reflects the communal living in rural Gambia where most settlements comprise extended families living in the same compound, with an average compound size of 33 persons in our study area. Such findings imply that households may be potential hubs for the spread of infections and school-aged children may play a significant role in the transmission of respiratory infection in households in this setting [7, 44].

In contrast to a previous study conducted along the rural coastal settings in Kilifi, Kenya, and spanning across two climatic seasons [10] which found no evidence of a difference in contact pattern by season, we found considerable seasonal variation in contact patterns. Although most contacts made across both seasons were physical, non-physical contacts were higher during the dry season compared to the rainy season. In contrast, more physical contacts were made during the rainy season compared to the dry season. Similar seasonal variations in contact patterns were observed in Taiwan [45]. These findings have significant implications for understanding the transmission of respiratory infections such as pneumonia. The PERCH study, which assessed the aetiology of childhood pneumonia in different countries including The Gambia, found that the "pneumonia season" in the Gambia was usually correlated with the rainy season [46]. Perhaps individuals are more likely to make physical contact during the cold rainy season to create a warm ambience and tend to avoid physical contact during the hot dry season. This difference in social behaviour by season may explain the findings of seasonal variation in contact intensity in this population.

Although males made a slightly higher number of contacts per day compared to females, there was no evidence of an effect of gender on contact patterns. This is consistent with observations made in Kenya [10], Uganda [38], and Malawi [31]. Most estimated contacts in this population were physical, occurred at home, and were relatively homogenous across age strata, which may explain the lack of effect of gender on contact patterns in our setting.

The reported contacts were mostly age-assortative, and physical, especially among children less than 15 years old. This finding is consistent with contact patterns in other settings [21]. School-aged children are highly active and tend to engage more in social interactions with their peers. Such findings have implications for the transmission of respiratory infections as school-aged children may serve as potential facilitators of respiratory disease transmission in the household and community. We also observed relatively high intergenerational mixing, particularly for older adults > 45 years. This may reflect household structures in rural settings where substantial mixing occurs between parents and children at home. These patterns of intra-household mixing suggest a potentially higher force of infection from older children to both younger children aged < 5 years and adults which may facilitate the spread of pathogens transmitted by close contacts at home.

More than half (54%) of the residents travel at least once a month to villages ≥ 5 km from their residence, spending almost half a day when they travel. Almost a third of residents travel to neighbouring villages < 5 km from their locations at least once a week. The frequent movement of people to other neighbouring towns in this setting could facilitate the spread of pathogens of epidemic potential, for example, the recent SARS-CoV-2 virus. This finding is important in consideration of targeted interventions in specific settings, particularly non-pharmacological interventions, to reduce the transmission of respiratory pathogens. Data on geographical mobility patterns coupled with contact patterns in specific settings could be important parameters for infectious disease transmission models.

There are some limitations to our study. Reported contacts are prone to recall bias as participants may not be able to recall all their contacts for the previous 24 h. Additionally, there is a possibility of reporting fatigue, especially for reported contacts that occurred outside the household. This may have resulted in an underestimation of reported contacts. To mitigate the risk of bias in reported contact data, we made two visits within 72 h; the first was collecting household demographics and priming the participant to make mental notes of their contacts. The second was collecting the recalled contacts. The accuracy of reporting is known to improve when individuals are primed in advance to report contacts [47]. Additionally, we observed that the proportion of contacts made at school was very low. This could largely be due to the use of parents and caregivers acting as proxies to estimate contacts of young children < 10 years, resulting in an underestimation of contacts at school. Furthermore, there were long periods of school vacations during the survey period. As previously described, a related study to assess the accuracy of proxy-reported contacts at school among a subset of school-going participants enrolled in this study found a mean of 17.0 observed contacts at school and proxy-reported contacts were often inaccurate with underreporting of contacts [12]. In our sensitivity analysis, we found that substituting reported with observed school-based contacts increased the weighted mean number of daily contacts from 12.7 to 16.0 [Additional file 3]. This demonstrates the likely underreporting of reported school contacts by parents and guardians who acted as proxies for their young children. Future research should aim to improve the accuracy of measurements in surveys of contact patterns. Thirdly, because the contact survey was primarily designed to provide input to inform mathematical modelling to understand pneumococcal transmission dynamics and to predict the impact of interventions, we oversampled the young child population. To mitigate the potential selection bias, post-stratification weights to calculate representative population-level estimates were applied. The exclusion of "casual contacts", many of which were non-physical contacts from our analysis, as well as not collecting information on "group contacts" which usually occur outside the household, may potentially bias our estimates towards household and physical contacts. Lastly, the results of this study may not be generalizable to urban settings in The Gambia as they differ in settlements, household structure and density.

Conclusion

We observed that social contact patterns in rural Gambia were primarily driven by household mixing. We found that contact mixing patterns were mostly age-assortative, particularly among school-aged children, and a large proportion of contacts were physical. Our study adds to the limited social contact data from Africa, especially from West Africa which has one of the highest burdens of infectious diseases that are spread through close contact. Our data can improve infectious disease transmission models of respiratory pathogens in high-transmission settings, which are useful for optimizing the delivery of different interventions. Modellers developing transmission models of respiratory infections should consider using the contact estimates from the sensitivity analysis [Additional file 4] to parameterize their models.

Abbreviations

BHDSS	Basse Health and Demographic Surveillance System
FWHDSS	Fuladu West Health and Demographic Surveillance Systems
DSS	Demographic Surveillance System
PVS	Pneumococcal Vaccine Schedules trial
MRCG	The Medical Research Council Unit The Gambia
PERCH	Pneumonia Etiology Research for Child Health
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-025-10640-z.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

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Author contributions

I. O and G. A. M and B. Y conceived and designed the study. E. M and G. S, supervised the collection of data. G. S. and O. J. and E. M. and I. O. extracted the data. I. O. and K. v. Z. and N. I. M. analyzed and interpreted the findings. I.O. drafted the paper. K. v. Z. and G. S. and B. G. and J. B. and S. F. and N. I. M. and B. Y. and G. A. M. reviewed drafts and provided input. All authors contributed to and approved the final version of the manuscript. The corresponding author had final responsibility for the decision to submit the paper for publication.

Data availability

Data that support the findings of this study have been deposited at https://doi.org/10.5281/zenodo.14064156. Population and school-based contact data are available on Zenodo via https://doi.org/10.5281/zenodo.13101862.

Declarations

Ethics approval and consent to participate

The study was approved by the Gambia Government/MRC Joint Ethics Committee (ref: 28705) and by the LSHTM Ethics Committee (ref: 28705). Written, informed consent to participate was obtained from all enrolled participants. Parents or guardians from the community provided consent for themselves and on behalf of child participants (age < 18 years). Child participants aged 12–17 years also provided assent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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