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Household-level risk factors for secondary influenza-like illness in a rural area of Bangladesh

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Abstract

OBJECTIVE To describe household-level risk factors for secondary influenza-like illness (ILI), an important public health concern in the low-income population of Bangladesh.

METHODS Secondary analysis of control participants in a randomised controlled trial evaluating the effect of handwashing to prevent household ILI transmission. We recruited index-case patients with ILI – fever (<5 years); fever, cough or sore throat (≥5 years) – from health facilities, collected information on household factors and conducted syndromic surveillance among household contacts for 10 days after resolution of index-case patients' symptoms. We evaluated the associations between household factors at baseline and secondary ILI among household contacts using negative binomial regression, accounting for clustering by household.

RESULTS Our sample was 1491 household contacts of 184 index-case patients. Seventy-one percentage reported that smoking occurred in their home, 27% shared a latrine with one other household and 36% shared a latrine with >1 other household. A total of 114 household contacts (7.6%) had symptoms of ILI during follow-up. Smoking in the home (RR_{adj} 1.9, 95% CI: 1.2, 3.0) and sharing a latrine with one household (RR_{adj} 2.1, 95% CI: 1.2, 3.6) or >1 household (RR_{adj} 3.1, 95% CI: 1.8–5.2) were independently associated with increased risk of secondary ILI.

CONCLUSION Tobacco use in homes could increase respiratory illness in Bangladesh. The mechanism between use of shared latrines and household ILI transmission is not clear. It is possible that respiratory pathogens could be transmitted through faecal contact or contaminated fomites in shared latrines.

keywords influenza, Bangladesh, sanitation, environmental tobacco smoke, air pollution, respiratory infections

Introduction

Annual influenza epidemics occur worldwide with sporadic pandemics. Influenza is an important aetiological agent for febrile illness and pneumonia among children in urban Dhaka, Bangladesh [1–3], where influenza incidence is approximately 100 episodes per 1000 child-years, and an estimated 10% of childhood pneumonia episodes are influenza-associated [2]. Influenza-like illness (ILI) refers to a syndrome with symptoms typical of influenza virus infection: fever with sore throat and/or cough [4]. In community-based surveillance in Bangladesh, 14% of all people who died during 2009, excluding those who died from injury, suicide or homicide, had symptoms of ILI within 14 days before death [5]. Although 2009 was a pandemic year, which may have influenced mortality from influenza, hospital-based surveillance indicates a similar incidence of influenza-associated ILI in 2008 (10 cases per 100 person-years), 2009 (6.6 cases of seasonal influenza and 4.4 cases of pandemic influenza per 100 person-years) and 2010 (17 cases per 100 person-years) [3].

In Bangladesh, influenza and ILI result in a high economic burden for families of ill individuals. Families of individuals with influenza identified during surveillance paid a median of 16% of monthly household income in out-of-pocket costs for treatment of influenza-associated illness [6]. Many families reported reducing monthly food expenditures and/or borrowing money in order to pay for treatment [6, 7]. Ill individuals may be unable to work and/or attend school for several days, further increasing the financial burden on families [6, 7].

Annual vaccination is a key strategy for the prevention of influenza in high- and middle-income countries [8]. In Bangladesh, as in many low-income countries, vaccination against influenza viruses has not been widely promoted, likely due to high costs and competing priorities of the healthcare system [9]. Non-pharmaceutical interventions that modify influenza transmission risk factors would be particularly useful in such a setting.

Respiratory virus transmission has been demonstrated in Hong Kong and the United States to be common among household contacts [10, 11]. Household contacts are in frequent contact with infected individuals and have similar risk factors to infected household members [10, 11]. Crowding and poor hand hygiene, which are prevalent in low-income settings, facilitate transmission of influenza and other respiratory viruses [12–15]. Handwashing has been associated with a reduced risk of acute respiratory infections in children [13, 16] and influenza transmission [11, 17] in high- and low-income settings. Exposure to indoor and ambient air pollution has been associated with an increased risk of all-cause acute respiratory infections [18–21]. Exposure to air pollution may damage lung tissue and compromise immunity, increasing susceptibility to respiratory infection [22, 23]. Air pollution concentrations in a home can be affected by tobacco smoking, biomass fuel use for cooking and proximity to biomass cookstoves [24, 25].

Influenza and ILI carry a high disease burden and subsequent economic burden in Bangladesh, a lower middle-income country where widespread pharmaceutical interventions may not be currently feasible or affordable for patients. However, most studies on non-pharmaceutical interventions for influenza have been conducted in high-income settings. It is, therefore, important to identify and address modifiable factors associated with secondary ILI, defined as ILI in another household compound member after the first patient has been identified, at the household level in Bangladesh and other high-burden, low-income settings in order to design interventions to reduce transmission. For this study, we aimed to identify household-level risk factors associated with secondary ILI in rural Bangladesh.

Methods

Study population

We conducted this analysis using the control group of a randomised controlled trial, Bangladesh Interruption of Secondary Transmission of Influenza Study (BISTIS) [26]. During the 2009 and 2010 influenza seasons, patients who sought care for respiratory symptoms at Jahurul Islam Medical College Hospital, two district health complexes, and six local pharmacies in rural Kishoreganj District, Bangladesh, were recruited as index-case patients. Study physicians screened patients for the presence of influenza-like illness (ILI), which was defined as fever in those less than 5 years of age and fever with cough or sore throat in those 5 years or older. As this study was investigating transmission of influenza at the household level, patients who were admitted to the hospital were ineligible to participate. Consenting index-case patients were accompanied to their home by study staff. Typically, residents of this area live with extended family members in compounds of several households, sometimes with a shared cooking space and a latrine. If at least two people other than the index-case patient intended to reside in the compound for the subsequent 20 days, we sought to enumerate and enrol all members of the compound (Figure 1).

Eligibility requirements

Eligibility requirements of index-case patients varied during the study period [26]. Briefly, in 2009, we recruited index-case patients who experienced symptom onset in the prior 7 days, who lived within 30 min travel time to the health facility, and had no ILI among household compound members in the prior 3 days ($n = 18$). Due to a lack of recruitment, after one month, we expanded this criteria to include those living within two hours' travel time and those with ILI in other household compound members ($n = 65$). In 2010, in response to literature indicating that handwashing was effective against influenza transmission within 36 h of symptom onset [11], we limited enrolment to index-case patients with symptom onset within 48 h. We allowed recruitment of those compounds where individuals who did not live in the index-case patient's home had ILI ($n = 103$). Full details of the eligibility requirements are described elsewhere [26]. Household contacts who had fever at enrolment ($n = 53$) were excluded from these analyses.

Randomisation to an intensive handwashing intervention or control arm was carried out at the compound level. Details of the handwashing intervention are described elsewhere [26]. The following analyses were conducted among participants randomised to the control group to reflect household-level risk factors for ILI.

Data collection and laboratory testing

At the initial healthcare facility visit of the index-case patient, a trained study physician procured specimens

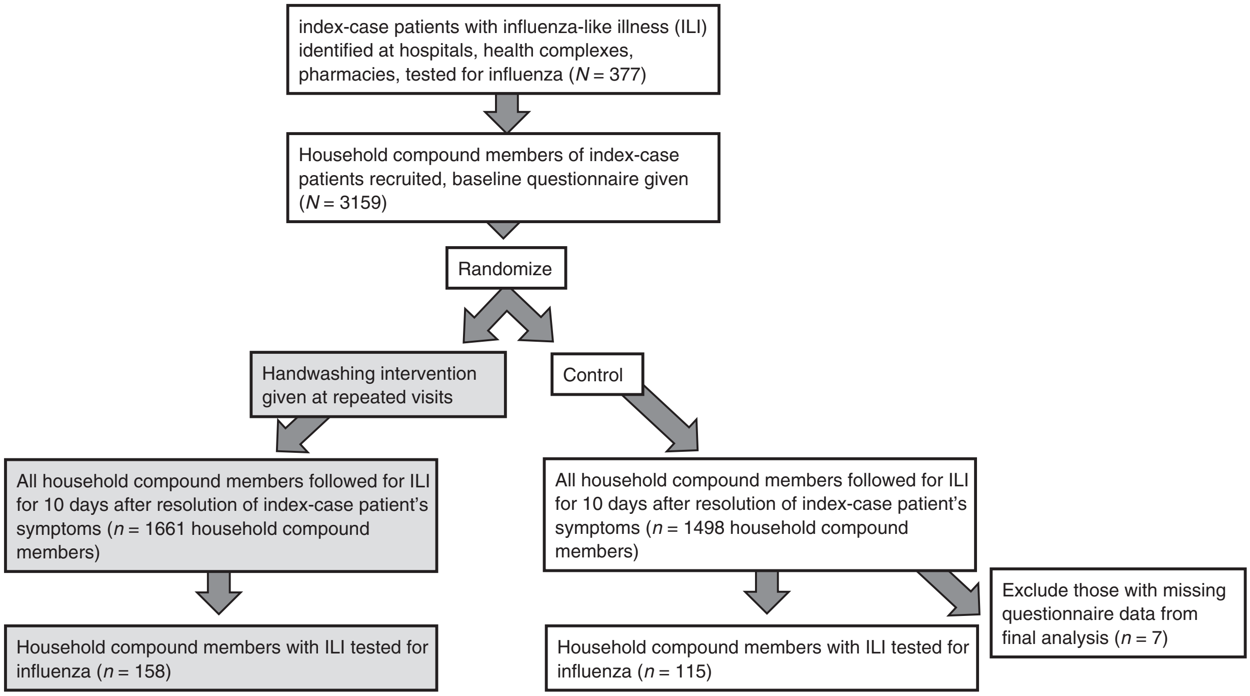

Figure 1 Schematic of participant selection for secondary analysis of household-level risk factors for influenza-like illness transmission. This analysis was limited to participants in the control arm.

using a nasal swab and an oropharyngeal swab, which were batched and tested by RT-PCR for influenza viral RNA using the World Health Organization protocol [27]. After index-case patients were recruited and tested for influenza virus infection, study staff accompanied index-case patients to their homes and recruited members of their compounds into the study. A staff member then administered a questionnaire to the male or female head of each household in the compound to assess demographics, socio-economic factors and individual- and household-level characteristics. The staff member observed each household for certain factors such as presence of a handwashing station with soap and water, location of cooking area, type of fuel used, water source and latrine facilities.

Study staff visited each household compound daily until the tenth day after resolution of the index-case patient's symptoms to conduct surveillance for ILI symptoms. Any member of the compound with new ILI symptoms during the follow-up period was considered a secondary ILI case. After consent was obtained, the secondary ILI case patients were tested for influenza in the same manner as the index-case patient.

Written informed consent for specimen collection was obtained from all adult index-case patients and secondary ILI cases. If the index-case patient or secondary ILI case was a child, written informed consent for specimen collection was obtained from a parent or guardian. Written informed consent was obtained from the head of the compound (typically the eldest male) for all household data collection activities. All study procedures were approved by the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) Research and Ethics Review Committees.

Data analysis

As few (n = 35) index-case patients had laboratory-confirmed influenza in the control arm, we included all index-case patients with ILI and conducted analyses to determine household-level risk factors associated with secondary ILI in household members. We examined the following household-level characteristics as potential risk factors for secondary ILI: crowding, building materials of homes, exposure to indoor air pollution, presence of handwashing materials, water source, latrine quality and sharing, education of the household respondent and household wealth status. Crowding was assessed as number of people per room (the number of people in the household divided by the number of rooms in the home, excluding latrine and kitchen). We assessed indicators of exposure to indoor air pollution, such as frequency of smoking in the home, cooking fuel use, building material of the home and the distance between the cooking and sleeping spaces. We observed handwashing materials, soap and/or water at a handwashing station [28]. We defined latrine quality as improved (flush/pour flush to piped sewer system, septic tank or pit latrine; or pit latrine with slab) or unimproved (flush/pour flush to elsewhere, open pit latrine, bucket, hanging latrine or no facility/bush/field), according to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. For socio-economic status, we examined education level of the household respondent and developed a wealth index using principal component analysis of household assets [29]. We used the first principal component as our wealth index and categorised it into quintiles. We also examined each household asset that weighed on the wealth index in principal components analysis as indicators of wealth.

We reported household-level factors potentially associated with ILI transmission at the household and individual levels. Those factors with 10–90% variability among all households were considered for multivariable analysis. We adjusted multivariable models for age of the index-case patient (<5 years, ≥5 years), as previous analyses showed age to be associated with ILI transmission in BISTIS [26]. We examined age of the susceptible contact as a potential confounder, both as a continuous variable and defined in the following categories: very young child (less than 2 years), young child (2–4 years), older child (5–14 years), adult (15–49 years) and older adult (50 years and older). We examined sex and wealth status of the susceptible household contact, as well as any factors associated with risk of ILI in the bivariate models ($P < 0.05$) as potential confounders. Since case definition varied by age, we conducted a sensitivity analysis in which we stratified analyses by age of the index-case patient (<5 years, ≥5 years). We also examined bivariate associations between household factors associated with secondary ILI and multiple daily interactions with the index-case patient (collected in 2010), as this was shown in our prior study to be associated with ILI [26].

We conducted mixed-effects log-binomial regression to evaluate the relationship between household-level factors and identification of a secondary case of ILI, adjusting for age of the index-case patient and the susceptible household contact, and we accounted for clustering at the household level. In order to evaluate independent associations, we adjusted models for all other household-level factors associated with secondary ILI in bivariate analyses ($P < 0.05$). We estimated the adjusted risk ratios of developing a secondary ILI case among those who lived in households with factors of interest compared with those who lived in households without the factors of interest.

Results

Among 1498 susceptible household contacts of 184 index-case patients, seven individuals (0.5%) from two households were excluded due to missing data. A total of 114 (7.6%) susceptible contacts developed ILI symptoms during follow-up. Among 1491 household contacts included in this analysis, 722 household members were from 181 index-case patient households and 769 from 182 households in the compound other than the index-case patient's household (Table 1). Houses typically consisted of one (50%) or two (30%) rooms, were made of brick or concrete (77%) and had a separate cooking space outside of the main living area (86%). Almost all households cooked with biomass fuels and used tube wells for drinking water. Smoking occurred in approximately 69% of homes. Of 1491 household contacts, 207 (14%) reported smoking; 197 (29%) of adult men were smokers vs. 10 (1.3%) of adult women (results not shown). Most (83%) household respondents had eight or fewer years of education. Our wealth index accounted for 31% of the variance in asset ownership. A total of 46 (40%) of the 114 secondary ILI cases lived in the index-case patient's household (Table 2).

In our final negative binomial regression models, we evaluated the independent associations between ever smoking in the home or sharing a latrine with one other household or more than one other household, and secondary ILI, adjusting for age category of the index-case patient (<5, ≥5 years). Models examining smoking in the home were also adjusted for shared latrine use, and models examining shared latrine use were also adjusted for smoking in the home. All other models adjusted for both smoking in the home and shared latrine use. Sex and age of secondary contacts were not included as model covariates, as sex was not associated with risk of secondary ILI in bivariate analysis, and addition of age of the secondary contact did not substantially change model estimates. Addition of further covariates resulted in unstable models.

In our final models, the risk of developing secondary ILI was 91% (95% CI 1.23–2.96) greater in those who lived in a household in which smoking ever occurred, compared with those who lived in a household with no smoking. Additional adjustment for education, wealth quintile and each individual asset that weighed on the wealth measure (ownership of a chair, table, mobile phone, watch or clock, sewing machine and electricity in the home) did not substantially change the estimates of the relative risk for ILI among those who lived in a

Table 1 Descriptive characteristics of households and contacts in control arm, Bangladesh Interruption of Secondary Transmission of Influenza Study, Kishoreganj, Bangladesh (*N* = 363 households, 1491 contacts)

	Households (*N* = 363) *n* (%)	Contacts (*N* = 1491) *n* (%)
Index-case patient household	181 (49.9)	722 (48.4)
Number of rooms in house		
1	183 (50.4)	638 (42.8)
2	109 (30.0)	471 (31.6)
3	47 (13.0)	221 (14.8)
4 or more	24 (6.6)	161 (10.8)
Mean (SD) number of people in household	4.6 (2.0)	5.5 (2.1)
Mean (SD) number of people per room	3.1 (1.6)	3.4 (1.7)
Building material of house		
Wood/thatch	17 (4.7)	61 (4.1)
Tin	68 (18.7)	288 (19.3)
Brick/concrete	278 (76.6)	1142 (76.6)
Biomass fuel use	345 (95.0)	1441 (96.7)
Mean (SD) number of steps from sleeping space to cooking space	7.9 (6.0)	8.0 (5.9)
Cooking space separated from living space*	312 (86.0)	1290 (86.5)
Smoking in house		
Ever	251 (69.1)	1055 (70.8)
Never	112 (30.9)	436 (29.2)
Materials at handwashing station		
Neither soap nor water	45 (12.4)	188 (12.6)
Water only	252 (69.4)	1016 (68.1)
Soap and water	66 (18.2)	287 (19.3)
Water source		
Deep tube well	238 (65.6)	969 (65.0)
Shallow tube well	114 (31.4)	478 (32.1)
Other	11 (3.0)	44 (3.0)
Improved latrine use	258 (71.1)	1047 (70.2)
Private latrine	117 (32.2)	548 (36.8)
Share latrine with one other household	100 (27.6)	401 (26.9)
Share latrine with >1 other household	146 (40.2)	542 (36.4)
Education level of respondent†		
Less than 1 year	141 (39.1)	582 (39.3)
1–4 years	56 (15.5)	241 (16.3)
5–8 years	100 (27.7)	398 (26.9)
More than 8 years	64 (17.7)	261 (17.5)
SES quintile		
Poorest	83 (22.9)	298 (20.0)
Second poorest	78 (21.5)	297 (19.9)
Middle	70 (19.3)	295 (19.8)
Second wealthiest	66 (18.2)	309 (20.7)
Wealthiest	66 (18.2)	292 (19.6)
Age of individual		
<2 years	NA	49 (3.3)
2–4 years		110 (7.4)
5–14 years		378 (25.4)
15–49 years		746 (50.0)
≥50 years		208 (14.0)

*Cooking space separated from living space indicates that there is at least one room between cooking space and living space or cooking space is not located in the same structure as the living space.
†Nine individuals from two households are missing education level of respondent.

household where smoking occurred compared with those who did not (RR_{Adj} between 1.85 and 1.94). Those who lived in a household with water at a handwashing station had a 29% lower risk of developing secondary ILI compared with those without water at a handwashing station, but this association was not statistically significant (95% CI 0.39–1.28). After adjustment, having soap and water at a handwashing station was not associated with risk of secondary ILI.

Compared with those living in a household with a private latrine, those who lived in households sharing their latrine with one other household were at a 2.07-fold increased risk of developing secondary ILI (95% CI: 1.18, 3.64) and those who shared their latrine with more than one other household had a 3.08-fold increased risk of developing secondary ILI (95% CI: 1.81, 5.23). Additional adjustment for education, wealth quintile and each individual asset that weighed on the wealth measure did not substantially change the estimates of the relative risk for ILI among those sharing a latrine with one other household (RR_{Adj} between 1.98 and 2.10) or among those sharing a latrine with more than one other household (RR_{Adj} between 3.00 and 3.12).

Living in the same household as an index-case patient, crowding (number of people per room), building material of home, water source and improved latrine use were not associated with risk of secondary ILI. In stratified analysis, associations between household-level risk factors and risk of secondary ILI did not substantially differ by age of index-case patient. Sex of the secondary contact and relationship of the secondary contact to the index-case patient were not associated with risk of developing secondary ILI in this analysis or in prior BISTIS analyses (results not shown) [30]. Multiple interactions with the

Table 2 Associations between household-level risk factors and secondary influenza-like illness (ILI) in BISTIS, Kishoreganj, Bangladesh (N = 1491)

	Secondary ILI (n = 114) n (%)	No ILI (n = 1377) n (%)	RR (95% CI)†	ARR (95% CI)‡
Index-case patient lives in same household	46 (40.4)	676 (49.1)	0.72 (0.49, 1.06)	0.89 (0.62, 1.31)
Mean (SD) number of people per room	3.5 (1.6)	3.4 (1.7)	1.04 (0.92, 1.17)	1.00 (0.89, 1.13)
Building material of house				
Concrete/brick	93 (81.6)	1049 (76.2)	REF	REF
Tin	16 (14.0)	272 (19.8)	0.68 (0.41, 1.13)	0.74 (0.46, 1.19)
Wood/thatch	5 (4.4)	56 (4.1)	1.01 (0.47, 2.18)	0.82 (0.38, 1.78)
Mean (SD) number of steps from sleeping space to cooking space	7.0 (4.6)	8.0 (6.0)	0.97 (0.93, 1.00)	0.98 (0.94, 1.02)
Cooking space separated from living space*	99 (86.8)	1191 (86.5)	1.03 (0.65, 1.63)	1.05 (0.68, 1.62)
Smoking in house				
Never	19 (16.7)	417 (30.3)	REF	REF
Ever	95 (83.3)	960 (69.7)	2.07 (1.29, 3.30)	1.91 (1.23, 2.96)
Materials at handwashing station				
Neither soap nor water	22 (19.3)	166 (12.1)	REF	REF
Water only	71 (62.3)	945 (68.6)	0.60 (0.35, 1.01)	0.71 (0.39, 1.28)
Soap and water	21 (18.4)	266 (19.3)	0.63 (0.33, 1.19)	0.97 (0.50, 1.86)
Water source				
Deep tube well	76 (66.7)	893 (64.9)	REF	REF
Shallow tube well	35 (30.7)	443 (32.2)	0.93 (0.63, 1.38)	1.06 (0.72, 1.55)
Other	3 (2.6)	41 (3.0)	0.87 (0.30, 2.54)	0.85 (0.33, 2.19)
Improved latrine use	77 (67.5)	970 (70.4)	0.88 (0.50, 1.30)	1.17 (0.79, 1.73)
Private latrine	19 (16.7)	529 (38.4)	REF	REF
Share latrine with one other household	33 (29.0)	368 (26.7)	2.37 (1.35, 4.17)	2.07 (1.18, 3.64)
Share latrine with >1 other household	62 (54.4)	480 (34.9)	3.30 (1.94, 5.61)	3.08 (1.81, 5.23)
P for trend			0.003	<0.0001
Education level of respondent				
Less than 1 year	47 (41.6)	535 (39.1)	REF	REF
1–4 years	25 (22.1)	216 (15.8)	1.28 (0.76, 2.14)	1.28 (0.77, 2.12)
5–8 years	27 (23.9)	371 (27.1)	0.84 (0.52, 1.34)	1.04 (0.66, 1.63)
More than 8 years	14 (12.4)	247 (18.1)	0.66 (0.37, 1.17)	0.89 (0.52, 1.50)
P for trend			0.3	0.8
Wealth status quintile				
Poorest	33 (29.0)	265 (19.2)	REF	REF
Second poorest	19 (16.7)	278 (20.2)	0.58 (0.33, 1.01)	0.62 (0.32, 1.20)
Middle	24 (21.1)	271 (19.7)	0.73 (0.43, 1.26)	0.99 (0.59, 1.68)
Second wealthiest	26 (21.9)	284 (20.6)	0.73 (0.43, 1.25)	1.05 (0.62, 1.79)
Wealthiest	13 (11.4)	279 (20.3)	0.40 (0.21, 0.79)	0.68 (0.38, 1.22)
P for trend			0.008	0.5

*Cooking space separated from living space indicates that there is at least one room between cooking space and living space or cooking space is not located in the same structure as the living space.
†Accounted for clustering on household level.
‡Adjusted for age category (<5, ≥5) of index-case patient, ever smoking in the home, sharing a latrine with one other household or more than one other household, and accounted for clustering on household level.

index-case patient were not associated with shared latrine use or smoking in the home (results not shown).

Discussion

In this study of household-level risk factors for ILI, we found that smoking in the home and sharing a latrine with other households were associated with increased risk of secondary ILI among household contacts. These results suggest that exposure to environmental tobacco smoke increases the risk of secondary ILI; there are several potential mechanisms for the increased risk of ILI due to shared latrine use. Both factors are potentially modifiable.

Our results support exposure to indoor air pollution from environmental tobacco smoke as a potential risk factor for ILI. Exposure to indoor air pollution is a well-established risk factor for all-cause acute respiratory infections, due to its detrimental effects on respiratory tissue and immune functioning in the respiratory tract [31–33]. Exposure to environmental tobacco smoke is also a well-established risk factor for numerous other conditions, including low birthweight, various cancers and chronic respiratory and cardiovascular diseases [34]. The prevalence of smoking in the home was high in this study, highlighting the need for tobacco control measures in Bangladesh. Greater use of effective tobacco control measures, such as taxation, could help to reduce tobacco smoking prevalence in Bangladesh [35]. The Global Adult Tobacco Survey estimated that 45% of adult men in Bangladesh smoke tobacco products [36]. In contrast, only 1.5% of adult women in Bangladesh smoke. Our study showed a lower proportion of men who smoke (29%) compared with the Global Adult Tobacco Survey. In our study, the household head reported tobacco smoking for all members of the household; it is possible that respondents may underreport smoking habits of other household members. Although biomass fuels are considered to be the major source of indoor air pollution in low- and middle-income countries [19, 32, 37], we were unable to assess the effect of biomass fuel use on secondary ILI, as nearly every participant (96.7%) reported using biomass fuels for cooking.

Sharing a latrine with at least one other household was the strongest exposure associated with secondary ILI observed in this study. Although shared latrines have not previously been shown to be associated with respiratory infections, there is some evidence of an association between shared latrines and diarrhoeal disease [38, 39]. Shared latrines may not be cleaned as frequently as private latrines [38], so it is possible that pathogens remain present longer on surfaces in shared latrines compared with private latrines. Contact transmission, by either direct contact with infected fluids or indirect contact via fomites, may be an important route of transmission for influenza and other respiratory pathogens [40, 41] as well as diarrhoeal pathogens [38]. Contaminated fomites in shared latrines, such as doors and traditional pots used for anal washing after defecation, may provide a route of transmission for pathogens in Bangladesh. As ILI may be caused by many different pathogens, it is possible that shared latrines may expose users to a number of different pathogens that may cause ILI symptoms. Specifically, influenza viruses [42, 43] and coronaviruses [44] have been recovered from faeces of patients, suggesting that some respiratory viruses may be transmitted through faecal contact. Interactions with people with influenza have been shown to be associated with risk of secondary influenza [45–49], and ILI [26]; it is plausible that those who use shared sanitation may have increased interactivity due to a commonly used resource (latrine). We did not observe an association between multiple daily interactions with the index-case patient and shared latrine use. However, we were unable to thoroughly investigate this possibility due to limited data. It is also possible that the association between sharing a latrine and ILI may be spurious or that latrine sharing represents a proxy for an unknown factor that is associated with ILI, but the effect estimates did not change substantially when adjusted for measures of wealth, age or smoking making this a less likely explanation.

Nearly 8% of household contacts reported ILI in this study. This proportion is similar to previous investigations of the burden of ILI in the general population of Bangladesh [5]. Although age of the index-case patient did not modify the effects of household-level risk factors on ILI, in this analysis and our prior analysis, ILI incidence was higher in susceptible contacts who were younger than 5 years compared with those who were 5 years or older [26]. Residing in the index-case patient's household was not associated with ILI risk, indicating that all members of a compound in a densely populated area are at risk of contracting infectious diseases from their compound members or the community at large.

Important limitations of this study include lack of detail regarding intra- *vs.* extra-household transmission pathways. We do not know whether pathogens were transmitted between members of the same household compound, whether they were acquired outside of the compound or whether the index-case patient we identified is in fact the primary ILI case in each compound. It is possible that control households had contact with intervention households and subsequently modified handwashing behaviour. However, our main study results do not suggest an association between handwashing and secondary ILI, so contact with the intervention arm is unlikely to have affected our results. As few participants had influenza, we did not test for other pathogens, and our definition of ILI for those under 5 years was broad, our results may not be relevant to influenza transmission, but rather, transmission of respiratory pathogens more broadly. Air pollution is a well-established household-level risk factor for respiratory illness [31–33], but reliable data on concentrations of household air pollutants are not available from this study. However, we did observe associations between indoor smoking, one proxy indicator of air pollution and secondary ILI incidence. As this study recruited participants from selected healthcare facilities, our sample may not be representative of people who sought care elsewhere [3, 5].

In addition, our sample may not be generalisable to urban Bangladesh, where there may be more crowding and more accessible health care.

Conclusions

Smoking in the home and use of shared latrines are associated with an increased risk of secondary influenza-like illness in households in this study. Our data highlight the possible benefit of efforts to reduce exposure to indoor air pollution from environmental tobacco smoke, including effective approaches to smoking cessation and clean air initiatives. Interventions focused on improving access to private latrines may also be helpful in low-income countries.

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