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Original Research

Use of biomass fuel and acute respiratory infections in rural Pakistan

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SUMMARY

Objective: To evaluate the association between use of biomass fuel and acute respiratory infection (ARI) episodes in children aged ≤5 years in Pakistan.
Design: Cross-sectional study.
Methods: Cluster sampling was used to select 566 children from 379 households in August–September 2007 in a rural setting in Pakistan. Information was collected on ARI episodes during the previous month and type of fuel used for cooking. Poisson regression with robust variance estimation was used to assess the association between use of biomass fuel and ARI episodes, adjusting for potential confounders.
Results: The incidence of ARI was 7 episodes/child/year. In the adjusted model, the incidence of ARI was higher in children living in houses where biomass fuel was used and who accompanied their mothers while cooking compared with children living in houses where fossil fuel was used and who did not accompany their mothers while cooking [rate ratio (RR) 2.6, 95% confidence interval (CI) 1.5–4.5]. Compared with the latter group, the incidence of ARI was also higher in children living in houses where biomass fuel was used but who did not accompany their mothers during cooking (RR 1.5, 95% CI 1.2–1.9), and in children living in houses where fossil fuel was used and who accompanied their mothers while cooking (RR 1.9, 95% CI 1.3–2.8).
Conclusion: Use of biomass fuel and presence of a child in the kitchen during cooking were associated with increased incidence of ARI in children aged ≤5 years.

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Introduction

Acute respiratory infections (ARI), particularly pneumonia, represent a leading cause of morbidity and mortality in children aged <5 years. Approximately 156 million episodes of pneumonia occur each year among children worldwide.[1] Thirty percent of deaths in children aged <5 years are attributed to ARI. The majority of episodes and deaths occur in Asia and Africa, of which >50% of cases occur in India, China, Pakistan, Bangladesh and Nigeria.[1] Pakistan is ranked third after India and China, with 9.8 million episodes of ARI in children aged <5 years.[1]

In order to achieve Millennium Development Goal 4 – to reduce the mortality rate in children aged <5 years by two-thirds between 1990 and 2015 – the incidence and related mortality of ARI need to be addressed.[2] Identification of risk factors plays an important role in designing effective interventions to reduce the incidence of ARI. The World Health Organization (WHO) has listed nutritional status, low birth weight and overcrowding as definitive risk factors, and exposure to biomass fuel as a potential risk factor, for pneumonia in developing countries.[1] Several studies from developing countries have reported an association between use of biomass fuel and increased risk of ARI.[3–7]

Biomass fuel, an ancient source of energy from biological origin (wood, bushes, tree leaves, cow dung, crop residues etc.), continues to be a major source of household energy for cooking in developing countries such as Pakistan. Biomass fuel, when burnt in raw form, results in inefficient combustion and produces chemicals/pollutants such as particulate matter (PM), carbon monoxide (CO), sulphur dioxide and nitrates, and other carcinogenic aromatic hydrocarbons.[8] In comparison with liquefied petroleum gas (LPG), wood and cow dung produce 19 and 64 times more CO, 17 and 115 times more hydrocarbons, and 26 and 63 times more PM, respectively.[9]

The use of biomass fuel is very common in Pakistan, with 66% of households (22% in urban areas and 90% in rural areas) using some form of biomass fuel.[10] This predisposes women (who do most of the cooking) and children to the risk of biomass-fuel-associated illnesses such as ARI. However, to the authors' knowledge, studies have not been conducted in Pakistan to assess the relationship between ARI in children and exposure to biomass fuel. As such, this study assessed the association between exposure to biomass fuel and ARI episodes among children aged ≤5 years in a rural setting in Pakistan.

Methods

Study design, setting and population

This cross-sectional study was conducted in Jhangara, a rural setting in Dadu district, Sindh province, Pakistan, in August and September 2007. In Jhangara, the maximum temperature ranged from 35 °C to 42 °C (mean 39 °C), and the minimum temperature ranged from 21 °C to 31 °C (mean 26 °C) in August and September 2007. The mean percentage humidity during the study period ranged from 60% to 84%. There was very little precipitation during this time. Healthcare in this area is provided by public health centres, general practitioners, nurses and unqualified practitioners. The study population comprised children aged ≤5 years residing in the study area.

Sampling design and recruitment of participants

A cluster sampling design was used to select households.[11] A cluster consisted of 50–100 households. Smaller villages were merged together and larger villages were divided to create clusters of equal sizes. Households were then selected using systematic sampling with a random start.[11] After verbal informed consent, the survey team collected information from households where a married woman aged 15–45 years and at least one child aged ≤5 years were residing. If there was more than one woman in a household, one was selected at random.

Outcome assessment

The outcome variable was ARI episodes among children aged ≤5 years in the household during the previous month as reported by the mother. To assess ARI, the researchers asked whether the child had experienced any respiratory complaints, including common cold/flu-like symptoms or breathing difficulties, during the previous month. If the mother answered affirmatively, detailed information was collected for each episode, including duration of the episode, symptoms, care sought and the type of healthcare provider.

Exposures and covariate assessment

The primary exposure of interest in the study was exposure to biomass smoke, which was ascertained by type of fuel used for cooking or heating. Fuel types were classified into: wood, crop residues, twigs gathered from trees and bushes, cow dung, coal, charcoal, kerosene, electricity, LPG, natural gas and other fuels. The question allowed multiple responses so respondents were able to select more than one fuel type. Wood, crop residues, twigs gathered from trees and bushes, cow dung, coal and charcoal were considered as biomass fuels. The use of kerosene oil, natural gas or LPG was classified as fossil fuel. Other exposure-related variables included kitchen layout, type of stove used, outlet for smoke (chimney/pipe), presence of windows/slits in the kitchen, presence of exhaust fan in the kitchen and frequency of its use, number of hours spent in the kitchen, and carrying the child while cooking (never, sometimes or always). Exposure monitoring studies have shown that fuel type and location of child while cooking are adequate predictors of child exposure to CO and PM.[12] Data on potential confounders such as environmental tobacco smoke, household assets (to create wealth index), mothers' age, education, ethnicity and crowding (number of rooms in the house/number of people in the household) were collected to adjust for their effect on the exposure–outcome relationship.

The nutritional status of children was assessed by measuring height and weight. For children aged <24 months, length was measured in a recumbent position, and weight was measured in an infant pan scale. For older children who were able to stand, their height and weight were measured in a standing position. WHO indices were used for evaluating nutritional status: weight for height, height for age and weight for age. The anthropometric indicators were converted to the z-score using the WHO standard population.[13]

Data analysis

Principal component analysis was used to construct a wealth index using items from household possessions, utilities and housing conditions. Each household item was assigned a score using the following expression[14]:

$$(\text{individuals value} - \text{mean for the sample})/\text{standard deviation for the variable} \times \text{factor loading}$$

The scores for all items were summed to create a linear index, and a final score was allocated to the households. The population was divided into wealth quintiles, with the first quintile representing the poorest households and the fifth quintile representing the richest households.

The rate of ARI episodes during the previous month and the rate of ARI episodes for which healthcare were sought were computed. The relationship between use of biomass fuel and number of ARI episodes was assessed using Poisson regression with robust variance estimation specifying exchangeable correlation structure implemented through Proc Genmod in SAS (Cary, NC). This technique accounts for the correlation of responses (clustering) at village level.[15] Adjusted rate ratios (RR) were calculated for the effect of use of biomass fuel on ARI while controlling for potential confounders. Analysis was performed using SAS Version 9.2 (Cary, NC).

Results

Participant characteristics

The study team approached 517 houses, and 390 households were eligible for interview. Eleven households refused to participate in the study. As such, 379 households with 381 women and 566 children were enrolled in the study (Fig. 1). The mean age of mothers was 30.7 [standard deviation (SD) 0.4] years and 332 (88%) had never been to school. One hundred and forty-seven (39%) women were underweight (body mass index $\leq$18.9 kg/m^2), and 243(64%) were anaemic [haemoglobin <11 g/dl, tested on portable HemoCue (Cypress, CA)]. Half (284, 50%) of the children were male, 168 (30%) were aged <12 months and 22 (4%) were aged 49–60 months. A large proportion of children (57%, 323) were underweight (weight for age <2 SD), 287 (50%) were stunted (height for age <2 SD) and 148 (26%) were wasted (weight for height <2 SD) (Table 1).

Use of biomass fuel at household level

In total, 81% (306/379) of households used biomass fuel: 21% (80/379) used wood, 36% (137/379) used twigs gathered from trees and bushes, and 15% (57/379) used cow dung and wood

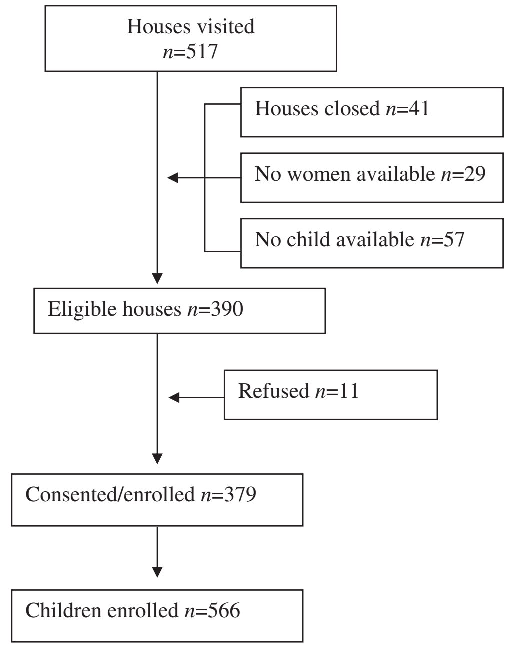

Fig. 1 – Enrolment of study participants in study on use of biomass fuel and acute respiratory illness in Sindh province, Pakistan, 2007.

(Fig. 2). The women spent an average of 4 h in the kitchen (SD 1.6, median 4, range 1–9 h). In most households, the stove was located outside the living and sleeping area [open outdoor cooking space: 302/379 (79%); enclosed outdoor kitchen: 25/379 (7%); indoor kitchen: 52/379 (14%)]. Among those who had an indoor or enclosed outdoor kitchen, 83% (43/52) had a window or other opening. Very few houses (7/52, 13%) had exhaust fans in the kitchen. A higher proportion of households using biomass fuel used an outdoor cooking space compared with those using fossil fuel (59% vs 85%), while a lower proportion of households using biomass fuel used an indoor kitchen (11% vs 24%).

Occurrence of ARI episodes

The incidence of ARI was 7 episodes/year/child aged $\leq$5 years. Approximately 46% (256) of children had experienced an ARI episode in the previous month (Table 1). Symptoms in the latest ARI episode included: runny nose (157/256, 61%), cough (178/256, 70%), difficulty breathing (72/256, 28%) and sore throat (18/256, 7%). Sixty-four percent (165/256) of children had experienced at least two symptoms. Most of those who had experienced an ARI episode (91%) had consulted a healthcare provider, and most of those who sought healthcare consulted a physician at a public clinic (72%) (Table 1). The mean number of symptomatic days was 9.0 (SD 2.5).

Relationship between use of biomass fuel and ARI

Children living in households where biomass fuel was used had a higher incidence of ARI compared with children living in

Table 1 – Characteristics of households, mothers and children enrolled in the study on use of biomass fuel and acute respiratory infection (ARI) among children in Sindh province, Pakistan, 2007.

Variables	*n*	%/mean[a]	SD
Household characteristics (*n* = 379)			
Type of house			
Concrete	94	24.8	6.3
Semi-concrete (walls concrete, roof wood, tin,asbestos tiles)	33	8.7	2
Walls wooden or mud/roof non-solid material	190	50.1	6.3
Wooden	8	2.1	1.2
Thatched hut	54	14.2	5.7
Wealth index quintile			
1st	75	19.8	4.9
2nd	97	25.6	5.6
3rd	60	15.8	4.1
4th	75	19.8	4
5th	72	19.0	5.7
Water source			
Tap inside house	168	44.3	7.8
Community tap	68	17.9	5.9
Tanker that bring water in the house	12	3.2	1
Community tanker	4	1.1	0.7
Boring/hand pump inside	11	2.9	1.1
Community boring/ hand pump	5	1.3	0.5
River/stream/fountain	63	16.6	5.1
Tube well	8	2.1	1
Underground well	40	10.6	3
Toilet facilities			
Use open space	198	52.2	8.4
Flush privy	96	25.3	8.1
Without flush	45	11.9	4
Closed pit	21	5.5	2.1
Use public latrines	19	5.0	1.6
Characteristics of mothers			
Age, mean[b]	378	30.7	0.4
Have never been to school, %	332	87.6	2.7
Employed, %	69	18.2	3.8
BMI, mean	379	20.3	0.4
BMI below normal (≤18.9, underweight)	147	38.8	2.8
BMI above normal (≥23, overweight)	66	17.4	2.3
Haemoglobin g/dl, mean	564	10	0.1
Anaemic (haemoglobin <11 g/dl), %	243	64.1	2.6
Characteristics of children (*n* = 566)			
Sex			
Male	284	50.2	1.6
Female	282	49.8	1.6
Age (months)			
<12	168	29.7	1.9
13–24	133	23.5	2.2
25–36	123	21.7	1.7
37–48	120	21.2	2.3
49–60	22	3.9	0.9
Prevalence of malnutrition among children			
Underweight (weight for age <2 SD), %	323	57.1	2.8

Table 1 – (*continued*)

Variables	*n*	%/mean[a]	SD
Severe malnutrition (weight for age <3 SD), %	253	44.7	2.6
Stunting (height for age <2 SD), %	287	50.7	2.6
Severe stunting (height for age <3 SD), %	157	27.7	2.9
Wasting (weight for height <2 SD), %	148	26.1	2.4
Severe wasting (weight for height <3 SD), %	20	3.5	0.9
Immunization status			
DPT1, % received	369	65.2	4.7
DPT3, % received	342	60.4	4.6
Respiratory complaints			
Had an episode of ARI during the previous month, %	256	45.2	2.4
Mean number of episodes	256	1.3	0.1
Consulted a healthcare provider (among those who had respiratory complaints), %	246	95.2	2.5
Mean number of symptomatic days	258	9	0.7
Consulted general practitioner, %	35	14.2	3
Consulted public hospital, %	176	71.5	3.6
Consulted public dispensary, %	15	6.1	1.6
Consulted private dispenser, %	20	8.1	1.5

BMI, body mass index; DPT, diphtheria, pertussis, tetanus; SD, standard deviation.
a Proportion for categorical variables and mean for continuous variables.
b Age missing for one woman.

households where fossil fuel was used [63.2 vs 43.5 episodes/100 children (RR = 1.3, 95% CI 1.1–1.5) (Table 2)]. ARI episodes were highest among children living in households that used cow dung and wood (103 ARI episodes/100 children), followed by wood alone (64 ARI episodes/100 children), and twigs from trees and bushes (52 ARI episodes/100 children).

The incidence of ARI in children living in houses where biomass fuel was used and who accompanied their mothers while cooking was higher than that in children living in houses where fossil fuel was used and who did not accompany their mothers while cooking (adjusted RR 2.6, 95% CI 1.5–4.5) (Table 3). Compared with the latter group, the incidence of ARI was also higher in children living in houses where biomass fuel was used and who did not accompany their mothers for most of the time during cooking (adjusted RR 1.5, 95% CI 1.2–1.9), and in children living in houses where fossil fuel was used and who accompanied their mothers while cooking (adjusted RR 1.9, 95% CI 1.3–2.8). The subsequent models adjusted for the additional variables which were not influential in the main model, but which have been reported as potential confounders (e.g. age, sex, nutritional status of child and mother's age) (Table 3).

In addition to use of biomass fuel, overcrowding, environmental tobacco smoke and exclusive breast feeding for >7 months were associated with greater incidence of ARI.

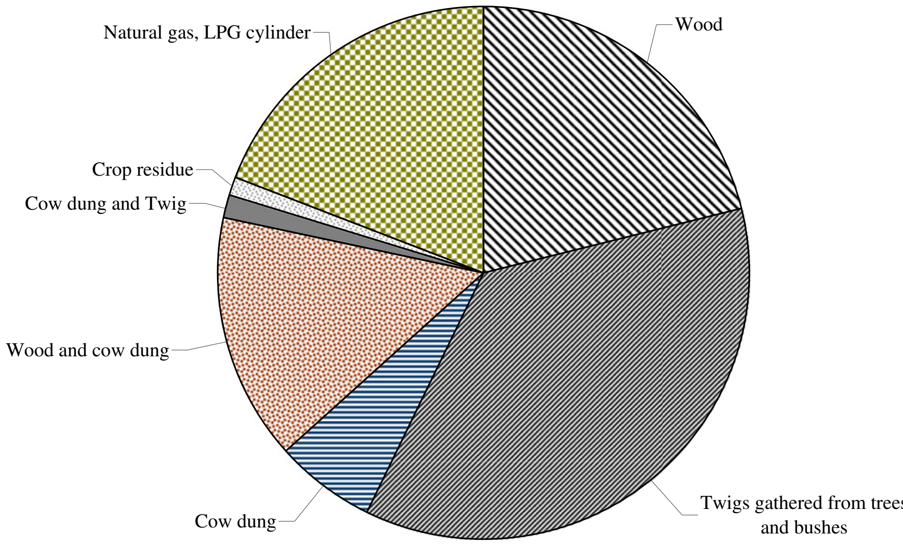

Fig. 2 – Fuel types used in study area. LPG, liquefied petroleum gas.

Discussion

These results from a rural setting in Pakistan demonstrate an association between use of biomass fuel at household level and ARI episodes among children aged ≤5 years. The incidence of ARI was higher among children living in houses where biomass fuel was used and who accompanied their mothers while cooking, and also among children living in these households who did not accompany their mothers while cooking. A recent national representative sample of a demographic and health survey conducted in 2006–2007 reported 89.6% biomass use in rural areas and 66.6% overall in Pakistan.[10] These proportions of biomass fuel use are similar to the results of the present study, although the distribution of the types of biomass used may differ depending on the local availability of fuel sources. Therefore, our results have implications for children in other rural areas in Pakistan.

The association between use of biomass fuel and a higher rate of ARI has important implications for reducing the incidence of ARI and resulting morbidity and mortality. The incidence of pneumonia in children in Pakistan is very high, contributing significantly to mortality in children aged <5 years. A study from the peri-urban community of Karachi reported incidence rates for ARI and pneumonia of 440/1000 children/year and 82/1000 children/year, respectively.[16] Thus, reducing the exposure of children to biomass fuel could have a significant effect on mortality and morbidity due to ARI, and could play an important role in achieving Millennium Development Goal 4. Reduction in exposure depends on the availability of cleaner fuels and ability to pay for such fuels. The availability of natural gas is limited to some parts of the country, and wood, which is a relatively clean fuel among biomass fuels, is expensive. Interventions based on reducing exposure rather than changing fuels may be more successful in the short term, as has been found in Guatemala where specific types of stoves were tested to reduce pollutants within the kitchen.[12,17,18] Similarly, a small pilot project in Pakistan successfully tested stoves that use biomass fuel but produce lower levels of pollutants.[19] However, there is need to assess the social acceptability and cost of the improved stoves for scaling up their use in Pakistan's rural settings.

This study found that the location of children at the time of cooking also determines their risk of acquiring ARI. If a child accompanied his/her mother in the kitchen while cooking, it increased the child's risk to ARI; this risk also existed when fossil fuel was used, but was much higher if biomass fuel was used. In developing countries such as Pakistan, the practice of carrying a child while cooking is common.[20,21] The mechanism by which biomass smoke can increase the risk of ARI is not well known. Biomass smoke contains many toxic compounds including PM of various sizes, CO, nitrogen and sulphur oxides, hydrocarbons, oxygenated organics such as aldehydes and phenols, and free radicals.[8,22] Pollutants produced when burning biomass fuel can penetrate deep into the lungs and produce various morphological and chemical changes in the respiratory tract, increasing susceptibility to infections. In animal models, exposure to biomass smoke has been shown to increase the risk of respiratory tract infections, and various mechanisms have been reported such as compromised pulmonary macrophage-mediated immune responses.[22–24] The level of pollutants (PM_{10} and $PM_{2.5}$) is higher in close proximity to the fire. Additionally, the highest levels of pollutants are produced when the fire is stoked.[25] Thus, children accompanying their mothers while cooking may receive a higher dose of pollutants than children who are not in close proximity to the fire.[20,25,26] Other studies have reported that a child's exposure to pollutants (PM_{10} and CO) is associated with the location of the child at the time of cooking and the amount of time spent in the kitchen.[12,27] Another study from Pakistan measuring PM also reported the presence of children aged <5 years in the kitchen during cooking when levels of $PM_{2.5}$ and PM_{10} were very high.[20] Khalequzzaman *et al.* found that levels of CO and CO_2 were comparable

Table 2 – Crude rate ratio and 95% confidence interval (CI) for association between use of biomass fuel and acute respiratory infection in Sindh province, Pakistan, 2007 (n = 566).

Variables	Rate ratio (RR)	95% CI	P
Fuel type			
Fossil fuel	1.0		
Biomass fuel	1.3	(1.1–1.5)	0.002
Household density			
Below median	1.0		
Above median	1.8	(1.3–2.4)	<0.001
Child accompanies mother in kitchen while cooking			
Never/sometimes	1.0		
Always	2.0	(1.4–2.9)	<0.001
Environmental tobacco smoke			
No	1.0		
Yes	1.7	(1.4–2.0)	<0.001
Wealth index quintile			
1st	1.0	(0.7–1.3)	0.79
2nd	0.8	(0.5–1.1)	0.16
3rd	0.6	(0.4–0.8)	0.005
4th	0.6	(0.5–0.8)	<0.001
5th	1.0		
Type of house			
Concrete	1.0		
Mud/wooden	1.3	(1.0–1.6)	0.06
Thatched	1.2	(0.8–1.8)	0.48
Nutritional status of child			
Underweight (yes/no)	0.8	(0.6–1.1)	0.24
Severe malnutrition (yes/no)	1.1	(0.9–1.3)	0.29
Stunting (yes/no)	1.1	(0.8–1.3)	0.64
Severe stunting (yes/no)	1.2	(0.5–2.9)	0.60
Wasting (yes/no)	0.9	(0.7–1.3)	0.73
Severe wasting (yes/no)	1.2	(0.5–2.9)	0.59
Kitchen location			
Outdoor	1.0		
Indoor	0.7	(0.2–1.8)	0.39
Outdoor (enclosed)	0.5	(0.4–0.8)	0.002
Sex of child			
Female	1.0		
Male	1.1	(0.9–1.4)	0.23
Age of child (months)			
<12	1.0		
13–24	1.1	(0.7–1.6)	0.66
25–36	0.8	(0.6–1.0)	0.02
>37	1.1	(0.8–1.6)	0.50
Duration of exclusive breast feeding (months)			
Below median (≤7 months)	1.0		
Above median (>7 months)	2.1	(1.6–2.9)	<0.001
Age of mother (years)			
18–24	0.6	(0.4–0.8)	<0.001
25–34	1.0		
>35	1.1	(0.8–1.4)	0.60
Maternal anaemia (haemoglobin <11 g/dl)			
No	1.0		
Yes	0.8	(0.6–1.0)	0.04
Fuel type and children in kitchen[a]			
Fossil fuel and children not in kitchen	1.0		
Biomass fuel and children not in kitchen	1.2	(1.1–1.4)	0.008
Fossil fuel and children in kitchen	2.3	(2.1–2.6)	<0.001
Biomass fuel and children in kitchen	2.4	(1.8–3.4)	<0.001

a Interaction term.

between biomass fuel and fossil fuel; this may explain the risk of ARI among children accompanying their mothers while cooking with fossil fuel in the present study.[21] Parental education and behavioural change strategies to keep children away from the kitchen during cooking could reduce the exposure of children and hence the risk of ARI.

Although the studies vary in terms of design, exposure measurement and outcome assessment, the present results for the association between use of biomass fuel and ARI incidence are similar to most studies from India (OR 4.0, 95% CI 2.0–7.9), Nepal (OR 2.3, 95% CI 1.8–2.9) Zimbabwe (OR 2.1, 95% CI 1.5–3.1), Gambia (OR 5.2, 95% CI 1.7–15.9), and a meta-analysis of these studies (OR 2.3, 95% CI 1.9–2.7).[3–7]

The following methodological issues should be considered when interpreting the present findings. This was a cross-sectional study with inherent temporal problems. However, in this case, the exposure was ongoing continuous use of biomass fuel, and the reference period for the outcome was the preceding month, so temporality violation may not be as extreme as in other situations where exposure is more discrete. A questionnaire was used to assess exposure that precludes quantification of pollutant levels. Exposure measurement studies have indicated that questionnaire-based exposure assessment is an adequate proxy for environmental measurement, and has been shown to predict levels of CO and $PM_{2.5}$.[12,27,28] Furthermore, questionnaire-based exposure assessment also allows assessment of behavioural factors that are important in exposure assessment. The outcome assessment in the present study was based on interviews with mothers, with a reference period of 1 month. When designing this study, a 1-month period was selected to balance recall with the number of events available for analysis. However, in cases where a child had experienced more than one ARI episode or a household had more than one child, the mother may have faced recall issues, especially under-reporting of milder disease.

Conclusion

This study found that use of biomass fuel was associated with increased incidence of ARI among children. This risk was higher if a child accompanied the mother during cooking. Given the very high proportion of households using biomass fuel for cooking in Pakistan, this study has important implications for the prevention of ARI among children in Pakistan. To reduce the incidence of ARI and related morbidity and mortality, short-

Table 3 – Adjusted models for association between use of biomass fuel and acute respiratory infection during the previous month in Sindh province, Pakistan, 2007 (n = 566).[a]

Variables	Adjusted rate ratio (95% confidence interval)				
	Base model	Addition of age and sex	Addition of nutritional status	Addition of mother's age	Addition of maternal anaemia
Fuel type and children in kitchen					
Fossil fuel and children not in kitchen	1	1	1	1	1
Biomass fuel and children not in kitchen	1.5 (1.2–1.9)	1.5 (1.2–1.8)	1.6 (1.2–2.0)	1.7 (1.3–2.2)	1.5 (1.2–2.0)
Fossil fuel and children in kitchen	1.9 (1.3–2.8)	2.1 (1.3–3.3)	2.2 (1.4–3.4)	1.4 (1.0–2.0)	2.4 (1.7–3.4)
Biomass fuel and children in kitchen	2.6 (1.5–4.5)	2.7 (1.5–4.6)	3.0 (1.7–5.3)	3.4 (2.0–5.8)	2.9 (1.7–5.0)
Household density					
Below median	1		1		
Above median	1.3 (1.0–1.8)	1.3 (1.0–1.8)	1.4 (1.0–1.9)	1.3 (0.9–1.8)	1.3 (0.9–1.8)
Environmental tobacco smoke					
No	1		1		
Yes	1.3 (1.1–1.6)	1.3 (1.1–1.6)	1.2 (1.0–1.5)	1.3 (1.0–1.5)	1.3 (1.0–1.5)
Wealth index quintile					
1st	0.7 (0.5–1.0)	0.7 (0.5–1.0)	0.7 (0.5–1.0)	0.7 (0.5–1.0)	0.7 (0.5–1.0)
2nd	0.6 (0.4–0.9)	0.6 (0.4–0.9)	0.6 (0.4–1.0)	0.7 (0.4–1.0)	0.7 (0.5–1.0)
3rd	0.5 (0.3–0.7)	0.5 (0.3–0.7)	0.4 (0.3–0.7)	0.4 (0.3–0.6)	0.4 (0.3–0.6)
4th	0.6 (0.4–0.9)	0.6 (0.4–0.9)	0.6 (0.4–0.9)	0.6 (0.4–0.9)	0.6 (0.4–0.9)
5th	1	1	1	1	1
Exclusive breast feeding, months					
Below median (≤7 months)	1	1	1	1	1
Above median (>7 months)	1.7 (1.2–2.4)	1.7 (1.3–2.4)	1.6 (1.2–2.3)	1.6 (1.2–2.2)	1.6 (1.1–2.2)
Sex					
Female		1	1		
Male		1.1 (0.9–1.4)	1.1 (0.9–1.3)	1.1 (0.9–1.3)	1.1 (0.9–1.3)
Age of child, months					
<12		1.3 (0.9–1.9)	1.2 (0.8–1.7)	1.2 (0.9–1.7)	1.3 (0.9–1.7)
13–24		0.9 (0.7–1.2)	0.9 (0.7–1.3)	1 (0.7–1.3)	0.9 (0.7–1.3)
25–36		1.2 (0.9–1.7)	1.2 (0.9–1.6)	1.2 (0.9–1.5)	1.2 (0.9–1.5)
>37		1	1	1	1
Stunting					
No			1	1	1
Yes			0.9 (0.7–1.2)	0.9 (0.7–1.2)	0.9 (0.7–1.2)
Age of mother, years					
18–24				0.8 (0.6–1.1)	0.8 (0.6–1.1)
25–34				1	1
>35				1.1 (0.8–1.5)	1.1 (0.8–1.5)
Maternal anaemia					
No					1
Yes					0.8 (0.6–1.0)

a Models based on generalized estimating equations (GEE) for count data specifying exchangeable correlation structure. The table presents the base model that include all variables significant in the multivariable model or produce >10% change in estimate of biomass fuel, and each subsequent model presents addition of potential confounder not influential in our study to the preceding model.

term interventions such as use of efficient stoves and educating mothers about keeping children away while cooking would be useful. In the long term, strategies should be developed for switching to cleaner fuels, which may require investment in infrastructure as well as economic development.

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Ethical approval

Ethics Review Committee, Aga Khan University Karachi, Pakistan.

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Competing interests

The data collection for this study was 'piggybacked' on to an evaluation of a community health and social development project in a rural area which was funded by ENI Pakistan Ltd which is an oil and gas company. However, the results presented in this paper were not part of that evaluation.

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