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## Abstract

**Background:** Household air pollution is a leading risk factor for respiratory morbidity and mortality in developing countries where biomass fuel is mainly used for cooking.

**Materials and Method:** A household cross-sectional survey was conducted in a predominantly rural area of Ghana in 2007 to determine the prevalence of respiratory symptoms and their associated risk factors. Household cooking practices were also assessed as part of the survey.

**Results:** Household heads of twelve thousand, three hundred and thirty-three households were interviewed. Fifty-seven percent (7006/12333) of these households had at least one child less than five years of age. The prevalence of symptoms of acute lower respiratory infections (ALRI) was 13.7% (n= 957, 95% CI 12.8 – 15.5%). A majority (77.8%, 95% CI, 77.7 - 78.5%) of households used wood as their primary fuel. Majority of respondents who used wood as their primary fuel obtained them by gathering wood from their neighborhood (95.6%, 9177/9595) and used a 3-stone local stove for cooking (94.9%, 9101/9595). In a randomly selected subset of respondents, females were the persons who mostly gathered firewood from the fields (90.8%, 296/326) and did the cooking (94.8%, 384/406) for the household.

**Conclusion:** Symptoms of ALRI reported by caregivers is high in the Kintampo area of Ghana where biomass fuel use is also high. There is the need to initiate interventions that use improved cook stoves and to test the health benefits of such interventions.

**Key words:** Acute Lower Respiratory infections, cooking practices, household air pollution, cook-stoves

## Introduction

Household air pollution is a leading risk factor for morbidity and mortality in developing countries (Bruce et al., 2000; Lim et al., 2012; Rehfuess et al., 2009; Smith, 2000). Although outdoor air pollution is an important and growing concern in sub-Saharan Africa, it has been estimated that household air pollution (HAP) is actually a more significant environmental health threat (Lim et al., 2012). World-wide, exposure to high levels of HAP is a daily reality for approximately 3 billion users of solid cook-fuels (WHO, 2014). The World Health Organization (WHO) estimates that HAP leads to about 4 million deaths per year and is one of the major global environmental risk factors for reduced life expectancy (WHO, 2014). In Ghana, solid fuels are utilized by a large majority of the population (GSS/GHS/GNPHRL, 2015) and solid fuel use accounts for 2.2 percent of the national burden of disease according to WHO estimates (WHO, 2007). This health burden is largely borne by women and especially children. Among women and children, HAP is associated with the risk of poor birth outcomes (Amegah et al., 2013; Kim et al., 2011; Lakshmi et al., 2013), cardiovascular diseases (Brook, 2007; Miller et al., 2007) and acute lower respiratory infection (ALRI) (Perez-Padilla et al., 2010; Torres-Duque et al., 2008).

In sub-Saharan Africa, the burden of ALRI is high (Walker et al., 2013) and contributes significantly to household expenditure or the health system (Sinha et al., 2012). Since HAP is one of the leading causes of ALRI, there is the need to develop interventions to reduce HAP in sub-Saharan Africa where the use of biomass as the main domestic energy is high (WHO, 2014). Meeting domestic energy while reducing the burden of ALRI may be a challenge and requires relevant local data that quantifies the magnitude of the current health burden and point to optimal solutions.

In 2007, the Kintampo Health Research Centre (KHRC) and Columbia University started a collaboration to develop innovative approaches that will help reduce household air pollution, with the goal of preventing poor health outcomes among rural populations in Ghana. In this paper, we report the results of a large, population-based household survey carried out with the goal of characterizing household cooking practices and respiratory morbidity among infants.

## Method

### Study area

The study was carried out in the Kintampo North Municipality and Kintampo South District of Ghana in 2007, with a total area of 7162 km<sup>2</sup> and a resident population of approximately 140,000 (Owusu-Agyei et al., 2012). The study area is located within the forest-savannah transitional zone in Ghana where community members are predominantly subsistent farmers, with literacy rate of about 40%. Malaria and respiratory infections are among the top ten diseases reported at health facilities (KNMA, 2013). There is significant poor ill-health among new-borns and infants; low birth weight prevalence is about 10% (Asante et al., 2013), neonatal mortality is 32/1000 live-birth, and infant mortality is 64/1000 child years (Kirkwood et al., 2010a). Health care is basic in the study area and the first point of call for an acute illness is a local chemical shop (Asante et al., 2010). This region has been under regular

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surveillance for births, deaths and migration patterns since 2003 by the Kintampo Health Research Centre (KHRC) under the Kintampo Health and Demographic Surveillance System (KHDSS) (Owusu-Agyei et al., 2012). The KHDSS platform provides the strength of contacting all households in the study area with a high response rate (Owusu-Agyei et al., 2012).

### Data Collection

The survey consisted of a short set of questions addressing childhood respiratory infections and household cooking practices that were administered to 12,333 households in the study area using the KHDSS. A more extensive questionnaire was later administered to a randomly selected sub-sample of 421 out of the 12,333 households to determine more details of household cooking practices. A trained fieldworker using a pretested questionnaire interviewed household heads or their representatives. A household was eligible for the survey if the respondent gave consent.

Key variables included household cooking practices, including type of cook-stove used in cooking, type of fuel used for cooking, description of primary cooks and cooking area. We also assessed the presence of respiratory symptoms (cough, blocked nose, runny nose, fast breathing; or difficulty in breathing) among the youngest child in the household in the 2 weeks prior to the interview. Questions were also asked regarding family structure, decision-making and economic circumstances. The time for each interview was about 45 minutes.

### Data Management and Analysis

Answered questionnaires were checked for completeness and consistency and sent to the KHRC computer laboratory for double entry into a password-protected database in Microsoft FoxPro version 9.0. Clean dataset was analyzed using Stata version 11.0 (Stata Corp, TX). Simple proportions and means were used to describe categorical and continuous data respectively. Socioeconomic status was defined using household assets such as household architecture or social amenities. Principal component analysis was applied to these variables and the first component was used as described others (Houweling et al., 2003; Howe et al., 2012; Vyas and Kumaranayake, 2006) The scores for the first component of wealth index were further classified into terciles as most poor, less poor and least poor.

### Ethical Consideration

Scientific and ethical approvals for the study were obtained from the Kintampo Health Research Centre Scientific Review Committee, the Kintampo Health Research Centre Institution's Ethics Committee (FWA00011103) and the Institutional Review Board of Columbia University. All participants were individually consented for voluntary participation in the study. The consenting process involved explaining the purpose of the study, confidentiality procedures, risks, benefits and freedom to opt out of the study at any time. Consent was indicated by a signature or thumbprint and a witness was used where respondent was illiterate. Completed survey forms have been kept safely under lock and key in KHRC and could be accessed only by named study investigators.

### Results

Twelve thousand, three hundred and thirty-three households were approached and interviewed with 100% response rate. As shown in Table 1, majority of household heads/respondents were males (61.5%) and with no education (54.1%). Most (67%) of households were located in rural areas.

**Table 1:** Characteristics of all households contacted (N= 12,333).

	n	%
Gender of household head		
Male	7585	61.5
Female	4339	35.2
Missing	409	3.3
Age of Household head in 2007		
20-39	4605	37.3
40-59	4782	38.8
60+	2449	19.9
Missing	497	4.0
Educational attainment of house head		
No education	6676	54.1
Primary	1003	8.1
Middle/JSS	2527	20.5
Secondary+	999	8.1
Missing	1128	9.2
Household size		
1	1314	10.6
2-5	2597	21.1
6-9	1988	16.1
10+	6025	48.9
Missing	409	3.3
Area of stay		
Rural	8265	67.0

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Urban	4068	33.0
Household wealth terciles		
Most poor	3980	32.3
Less poor	3942	32.0
Least poor	4002	32.4
Missing	409	3.3
Cigarettes smoking in the last month		
Yes	1687	13.7
No	10646	86.3
Commercial cooking		
Yes	1765	14.3
No	10568	85.7

The prevalence of smoking among household members was 13.7% within the one month period prior to the survey. Approximately fifty-seven percent (7006/12333) of households had at least one child less than five years of age. Fifty-two percent of children were males [Table 2].

### Prevalence of at Least One Respiratory Symptom and Potential Risk Factors

At least one respiratory symptom (cough, blocked nose, fast breathing, or chest in drawing) was reported in 34.4% (n=2413, 95% CI 33.3 - 35.5) of children <5 years of age (N=7006). A majority (51.9%) of children with at least one respiratory symptom lived in households with a male head, with those in the rural areas going up to 65.3%. Also 99.3% of male-headed households used biomass fuel (wood or charcoal) as the main primary fuel (Table 2). Blocked nose was the commonest symptom reported (29.6%, 95% CI: 28.4 – 30.6) (Figure 1). Seventeen percent (413/2413) of children who were reported to have had at least one respiratory symptom sought medical treatment.

### Prevalence of ALRI Symptoms and Potential Risk Factors

The prevalence of ALRI symptoms (cough with fast breathing and/or difficulty in breathing) was 13.7% (n= 957, 95% CI: 12.8–15.5%). A majority of children with ALRI symptoms lived in households with household heads who had no education (51.9%) and also in households that used biomass fuel (98.8%) as the main primary fuel (Table 2).

### Cooking Practices

In all households contacted, a majority (77.8%, 95% CI 77.7 - 78.5%) of households used wood as their primary fuel (Table 3). Majority of respondents who used wood as their primary fuel obtained them by gathering wood from their neighborhood (95.6%, 9177/9595) and used a 3-stone local stove for cooking (94.9%, 9101/9595). Charcoal use was less common (Table 3). LPG or electricity use was rare (Table 3). A majority of respondents primarily cooked in open areas with no roofs and walls (56.7%). Partially enclosed areas were the commonest (38.0%) secondary cooking area (Figure 2). None of the cooking practice variables was significantly associated with respiratory symptoms.

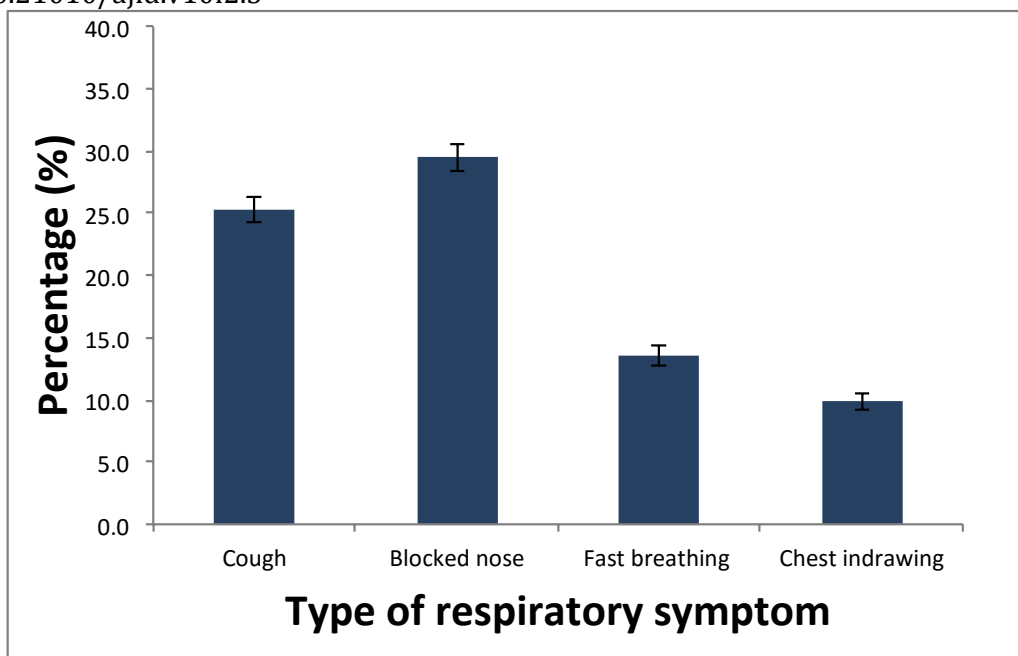
**Table 2:** Characteristics of households and characteristics of children assessed for respiratory morbidity

	Total	At least one respiratory sign. n (%)		Symptoms of acute lower respiratory infection. n (%)	
	N=7006 n (%)	N=2413 Yes n(%)	N=4593 No n(%)	N=957 Yes n(%)	N=6049 No n(%)
Gender of household head					
Male	4624 (66.0)	1589 (65.8)	3035 (66.1)	609 (63.6)	4015 (66.4)
Female	2176 (31.1)	748 (31.0)	1428 (31.1)	311 (32.5)	1865 (30.8)
Missing	206 (2.9)	76 (3.2)	130 (2.8)	37 (2.9)	169 (2.8)
Age of Household head at time of survey					
20-39	3050 (43.5)	1077 (44.6)	1973 (43.0)	439 (45.9)	2611 (43.2)
40-59	2592 (37.0)	884 (36.6)	1708 (37.2)	331 (34.6)	2261 (37.4)
60+	1118 (16.0)	361 (15.0)	757 (16.5)	143 (14.9)	975 (16.1)
Missing	246 (3.5)	91 (3.8)	155 (3.6)	44 (4.6)	201 (3.3)
Educational attainment of house head					
No education	3810 (54.4)	1301 (53.9)	2509 (54.6)	497 (51.9)	3313 (54.8)
Primary	587 (8.4)	185 (7.7)	402 (8.7)	66 (6.9)	521 (8.6)
Middle/JSS <sup>a</sup>	1400 (20.0)	475 (19.7)	925 (20.1)	204 (21.3)	1196 (19.7)
Secondary+	523 (7.4)	197 (8.2)	326 (7.1)	90 (9.4)	433 (7.2)
Missing	686 (9.8)	255 (10.5)	431 (9.4)	100 (10.5)	586 (9.7)
Household size					
1	620 (8.8)	255 (10.6)	365(7.9)	113 (11.8)	507 (8.4)
2-5	1395 (19.9)	490 (20.3)	905 (19.7)	216 (22.6)	1179 (19.5)
6-9	1074 (15.3)	381 (15.8)	693 (15.1)	124 (13.0)	950 (15.7)
10+	3711 (53.0)	1211 (50.2)	2500 (54.4)	467 (48.8)	3244 (53.6)
Missing	206 (2.9)	76 (3.1)	130 (2.8)	37 (3.8)	169 (2.8)

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Area of residence					
Rural	4855 (69.3)	1577 (65.3)	3278 (71.4)	558 (58.3)	4289 (71.0)
Urban	2151 (30.7)	836 (34.7)	1315 (28.6)	399 (41.7)	1752 (29.0)
Cigarettes smoking in the last month					
Yes	1042 (14.9)	376 (15.6)	666 (14.5)	139 (14.5)	903 (14.9)
No	5964 (85.1)	2037 (84.4)	3927 (85.5)	818 (85.5)	5146 (85.1)
Household wealth terciles					
Most poor	2137 (30.5)	755 (31.3)	1382 (30.1)	283 (29.6)	1854 (30.7)
Less poor	2381 (34.0)	824 (34.1)	1557 (33.9)	322 (33.6)	2059 (34.0)
Least poor	2282 (32.6)	758 (31.4)	1524 (33.2)	315 (32.9)	1967 (32.5)
Missing	206 (2.9)	76 (3.2)	130 (2.8)	37 (3.9)	169 (2.8)
Commercial cooking in household					
Yes	1082 (15.4)	420 (17.4)	662 (14.4)	775 (81.0)	5149 (85.1)
No	5924 (84.6)	1993 (82.6)	3931 (85.6)	182 (19.0)	900 (14.9)
Sex of youngest child					
Male	3627 (51.8)	1300 (53.9)	2327 (50.7)	3100 (51.3)	527 (55.1)
Female	3345 (47.7)	1102 (45.7)	2243 (48.8)	2917 (48.2)	428 (44.7)
Missing	34 (0.5)	11 (0.4)	23 (0.5)	32 (0.53)	2 (0.21)
Age of child					
0	1626 (23.2)	594 (24.6)	1032 (22.5)	251 (26.2)	1375 (22.7)
1	1851 (26.4)	696 (28.8)	1155 (25.1)	287 (30.0)	1564 (25.9)
2	1857 (26.5)	588 (24.4)	1269 (27.6)	214 (22.4)	1643 (27.2)
3	841 (12.0)	281 (11.6)	560 (12.2)	98 (10.2)	743 (12.2)
4	831 (11.9)	254 (10.6)	577 (12.6)	107 (11.2)	724 (12.0)
Primary cooking fuel					
LPG/ Electricity	16 (0.2)	8 (0.3)	8 (0.2)	4 (0.4)	12 (0.2)
Biomass fuel (Wood/ Charcoal)	6957 (99.3)	2390 (99.1)	4567 (99.4)	945 (98.8)	6012 (99.4)
Other	33 (0.5)	15 (0.6)	18 (0.4)	8 (0.8)	25 (0.4)
Primary cooking area					
Open with no roof and walls	4071 (58.1)	1360 (56.3)	2711 (59.0)	556 (58.1)	3515 (58.1)
Open with roof only	433 (6.2)	154 (6.4)	279 (6.1)	62 (6.5)	371 (6.1)
Partially enclosed with walls and roof	1260 (18.0)	484 (20.1)	776 (16.9)	187 (19.5)	1073 (17.8)
Fully enclosed	1227 (17.5)	413 (17.1)	814 (17.7)	151 (15.8)	1076 (17.8)
No primary cooking area	15 (0.2)	2 (0.1)	13 (0.3)	1 (0.1)	14 (0.2)
Stove for burning wood					
Open <i>mokya</i> <sup>b</sup>	5764 (82.3)	1975 (81.9)	3789 (82.5)	748 (78.2)	5016 (82.9)
Clay <i>mokya</i> <sup>b</sup>	197 (2.8)	69 (2.9)	128 (2.8)	35 (3.7)	162 (2.7)
Metal <i>mokya</i> <sup>b</sup>	131 (1.9)	23 (0.9)	108 (2.3)	10 (1.0)	121 (2.0)
Other	29 (0.4)	12 (0.5)	17 (0.4)	7 (0.7)	22 (0.4)
Do not use wood	885 (12.6)	334 (13.8)	551 (12.0)	157 (16.4)	728 (12.0)
Way in obtaining wood					
Gather from the field only	1287 (18.4)	449 (18.6)	838 (18.3)	721 (75.3)	5059 (83.6)
Gather from the field and purchase from market	120 (1.7)	54 (2.2)	66 (1.4)	15 (1.6)	75 (1.3)
Purchase from the market only	2455 (35.0)	950 (39.4)	1505 (32.8)	63 (6.6)	190 (3.1)
Do not gather wood	3144 (44.9)	960 (39.8)	2184 (47.5)	158 (16.5)	725 (12.0)

<sup>a</sup>JSS – Junior Secondary School <sup>b</sup>*Mokya* – A local stove



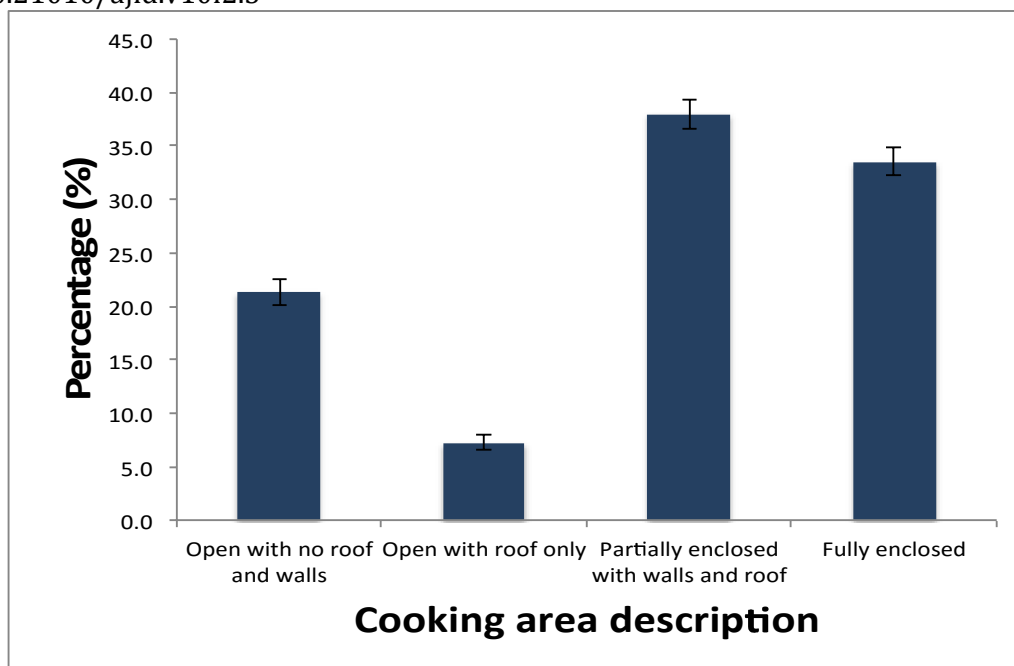
**Figure 1:** Bar chart of Prevalence of respiratory morbidity among children in the last two weeks prior to the survey (with confidence intervals).

Legend: Bar chart of the prevalence of respiratory symptoms among children less than five years old (N=7006) in the Kintampo area, 2007. Numerator (n) for each symptom is as follows: cough =1775, blocked nose/runny nose=2070, fast breathing =944, chest in-drawing =692

**Table 3:** Cooking practices among all households N=12,333

	N	%
Primary cooking fuel		
LPG/ Electricity	63	0.5
Charcoal	2364	19.2
Wood	9595	77.8
Other	311	2.5
Primary cooking area		
Open with no roof and walls	6996	56.7
Open with roof only	748	6.1
Partially enclosed with walls and roof	2208	17.9
Fully enclosed	2101	17.0
No primary cooking area	280	2.3
Stove for burning wood		
Open mokyia	9691	78.6
Clay mokyia	319	2.6
Metal mokyia	214	1.7
Other	41	0.3
Do not use wood	2068	16.8
Way in obtaining wood*		
Gather	9660	78.3
Gather and purchase	150	1.2
Purchase	455	3.7
Do not use wood	2068	16.8

\*Includes respondents who use wood as their primary or secondary source of fuel.



**Figure 2:** Proportion of secondary cooking areas among all households that had a secondary cooking area (N= 4825). Numerator (n) for each secondary cooking area is as follows: Open with no roof and walls =1027, Open with roof only =348, partially enclosed with walls and roof= 1833, fully enclosed=1617

**Table 4:** Source of information among households (N=12,333)

Source	Agricultural information		Health information	
	N	%	N	%
Radio	6,813	55.2	6,338	51.4
Nearby neighbors	1,275	10.3	302	2.5
Agricultural officer	877	7.1	26	0.2
Community elders	810	6.6	313	2.5
Other	384	3.1	80	0.7
Other community members	330	2.7	210	1.7
Health officer	47	0.4	4,285	34.7
Extended family	26	0.2	12	0.1
Friend elsewhere	24.0	0.2	8	0.1
NK	1,747	14.2	759	6.2

In a randomly selected subset of respondents, females were the persons who mostly gathered firewood from the fields (90.8%, 296/326) and did the cooking (94.8%, 384/406) for the household; 58.7% (247/421) of households cooked on their farms outside their homes. In the same subset of households, 74% (313/421), 47.7% (201/421), and 93.6% (394/421) of households cooked breakfast, lunch, or supper respectively. The median time for cooking was 2 hours and 20 minutes (range 0 – 5 hours, 30 minutes).

#### Awareness of Cook-Stoves and Health Risk of Smoke

In the randomly selected subset of households, a majority (92.4%, n=389/421) of respondents were not aware of improved cookstoves. However, most respondents were aware of health hazards associated with smoke. About 97.4% (410/421) were aware that tobacco could lead to health hazard and cook smoke could lead to childhood pneumonia (96.7%, n=407/421) or lung disease in adults (96.4%, n=406/421). Other sources of smoke identified by household members were those from mosquito coils (39.7%, 167/421) as well as from paraffin or kerosene lantern (92.6%, 390/421).

#### Household Decision-Making and Sources of Information

In all households, fathers/husbands were the primary decision makers for households in health seeking (64.3%, 7924/12,333) or for major item purchases (67.2%, 8286/12,333). Mothers/wives made primary decisions in 25.4% (3135/12,333) of health-seeking in households and 23.1% (2850/12,333) for major items purchases. The local radio was the commonest primary source of agricultural (55.2%) or health (51.4%) information (Table 4). Other sources included agricultural officers or health officers.

**Discussion**

A survey was conducted in a predominantly rural area of Ghana to determine household respiratory morbidity and cooking practices among young children. The prevalence of at least one respiratory symptom (cough, blocked nose, fast breathing, or chest in drawing) was very high among children who were less than five years of age at the time of the survey. Cough was one of the commonest symptoms reported. The reported cough could be pathological or non-pathological (Bonney et al., 2012). Though it is likely that a proportion of the symptoms reported may not be pathological, the prevalence of runny nose suggests a high probability of an upper respiratory tract infection (URTI). URTI may result from common viruses such as *Influenza Sp* that sometimes occur as outbreaks but are usually eliminated within a short period (i.e. within periods less than 6 months) (Iskander et al., 2013). It could have been possible an URTI outbreak occurred at the time of this survey, but this was unlikely as there was no report of such an outbreak by health authorities in our surveyed area in the six-month period of our survey. The prevalence of respiratory symptoms determined in this survey is similar to that obtained in other surveys in rural areas of Kenya (Feikin et al., 2011), and in industrialized countries where air pollution is high (Kumar et al., 2007; Ranzi et al., 2014).

The prevalence of ALRI symptoms (13.7%), though lower than that of URTI represents a significant health burden if they truly reflect underlying ALRI prevalence. In studies conducted in southern Ghana, the prevalence of ALRI symptoms assessed by trained community health personnel was <10% (Chinbuah et al., 2013). In our study, ALRI symptoms were reported by mothers or caregivers and not by health professionals or trained community volunteers. It is therefore likely that the prevalence determined in this survey could have been under-estimated since mild to moderate breathlessness or chest in-drawing may go unnoticed by the mother as was found in surveys in other parts of Ghana (Denno et al., 1994) and in Ethiopia (Muhe, 1996).

The use of firewood for cooking was very high in the study area and similar to other rural areas of Ghana and developing countries (Bonjour et al., 2013; GSS/GHS/GNPHRL, 2015). Uncontrolled, unventilated firewood combustion leads to air pollution, which is associated with high disease burden including respiratory diseases (Thacher et al., 2013; Wong et al., 2013). In this survey, no associations were sought between use of firewood and respiratory symptoms. This is due to the fact that few households (0.5%) used clean cook stoves or fuels (electricity or LPG) as their primary cooking fuel and we lacked exposure monitoring at the time of the survey to test for exposure-response among those families using wood for cooking. Respiratory symptoms were higher among children living in urban areas. It is likely that the children living in urban areas are exposed to other risk factors of respiratory signs such as smoke from vehicles.

A majority of households primary cooks were women of childbearing age. We assume that, if pregnant, the foetus of these primary cooks were likely to be exposed to environmental pollutants such as carbon monoxide that may lead to poor health outcomes (Naeher et al., 2000). The GRAPHS study (Jack et al., 2015) currently under way in Ghana is seeking to evaluate the potential impact of use of improved cook-stoves on low birth weight and infant respiratory morbidity and will be able to provide additional data to help explain this assumption being made in the manuscript. Other cohort studies will be required to investigate the potential impact of using improved cook-stoves on other infant health outcomes such as motor and neurodevelopment and infant anthropometry growth.

In many developing sub-Saharan countries, government policies recognize the need to provide improved cook-stoves as means of maintaining trees and plantations to halt climate change (Kgathi and Zhou, 1995). In Ghana, pilot programmes are being implemented by providing free LPG stoves to some rural communities. There is the need to take advantage of such programmes to assess the health benefits of improved cook-stoves on non-communicable diseases such as cardiovascular diseases. In planning such intervention studies, there is the need to consider the social context within which the study will be carried out. In the current study, knowledge of improved cook-stoves is documented to be limited. Community members will therefore need to be educated on the use of the chosen improved cook-stove to ensure compliance through an appropriate medium. Community durbars and community worker discussion of topical issues in the study were found to be the best ways of deploying information. Even though, interventions of this nature may be targeted at women and their children, household decision makers will need to be consulted to ensure acceptance and compliance to the improved cook-stove as majority of households decisions are made by male household heads.

**Study Limitation**

A cross-sectional survey was conducted and therefore temporal relationship between use of cook-stoves and respiratory symptoms cannot be assessed. Secondly the symptoms such as breathlessness was not counted but was dependent on the subjective observations of the mother or caregiver of the child. Studies will however require counting and observations by a trained health professional or community worker as was used in other studies in Ghana (Kirkwood et al., 2010b) and the RESPIRE study (Smith et al., 2011).

**Conclusion**

Symptoms of ALRI reported by caregivers are high in the Kintampo area of Ghana where use of biomass fuel use is also high. There is the need to plan interventions to use improved cook-stoves and to test the health benefits of such interventions.

**Competing Interest:** All authors declared that they have no competing interest.

**Authors' contribution**

KP, DJ, SOA and PK conceived the idea. All authors contributed to the study implementation. KP and EN analyzed the data. KP wrote the first draft of the paper and the final version was reviewed and approved by all authors. SOA, the Director of the Kintampo Health Research Centre and PK, the Director of Columbia Climate and Health Program, Department of Environmental Health Sciences, Mailman School of Public Health reviewed and approved the paper on behalf of the participating institutions.

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