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Association of household cooking location behaviour with acute respiratory infections among children aged under five years; a cross sectional analysis of 30 Sub-Saharan African Demographic and Health Surveys

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Abstract

Background: Cooking location among households using solid biomass cooking fuels may have implications for exposure to harmful levels of Household Air Pollution (HAP). However, little is known about the predictors of cooking location and their association with Acute Respiratory Infections (ARI); a leading cause of mortality in children aged under five years worldwide and has child national status, vaccination status and season as risk factors

Objectives: This cross-sectional study aimed to ascertain (i) the determinants of household cooking location behaviour and (ii) the association between cooking location and risk of respiratory symptoms and ARIs in children under five years residing in solid biomass cooking households, using Demographic and Health Survey data from Sub-Saharan Africa (SSA).

Methods: Data were obtained for 30 SSA countries including of 263,948 children aged under five years living in solid biomass burning households only. The occurrence of respiratory symptoms (cough, shortness of breath) and fever in the two weeks prior to interview were obtained by maternal-report; generating composite variables for ARI (shortness of breath, cough) and severe ARI (SARI) (shortness of breath, cough, fever). Associations for determinants of household cooking location behaviour, respiratory symptoms and ARIs were determined through logistic regression analysis, adjusting for country, regional, household and individual-level confounding factors.

Results: After adjustment, outdoor cooking was more likely among households with lower wealth index, younger and lower educated household heads, fewer household members, cooking fuel type (charcoal, coal), empowered females, urban place of residence, wet season, compared to indoor. Reduced odds ratios of SARI (AOR:0.87[0.80-0.94]), ARI (AOR:0.89[0.83-0.95]), cough (AOR:0.90[0.86-0.95]), shortness of breath (AOR:0.91[0.85-0.89]) and fever (AOR:0.85[0.81-0.89]) were observed among children residing in outdoor compared to cooking in the house. In rural areas only outdoor cooking was associated with reduced odds ratios of cough (AOR:0.89[0.82,0.95]), fever (AOR:0.86[0.79-0.92]), ARI (AOR:0.92[0.87-0.96]) and SARI (AOR:0.86[0.77-0.95]). However, in urban areas cough (AOR:0.90[0.82-0.98]), shortness of breath (AOR:0.89[0.79-0.99]), fever (AOR: 0.81[0.75-0.88]) and ARI (AOR:0.88[0.78-0.99]) were associated with outdoor cooking.

Discussion: Outdoor household cooking locations mitigates HAP exposure and is associated with reduced respiratory health impacts among children aged under five years in resource poor settings. Further mixed-methods research is necessary to understand enablers and barriers of outdoor cooking among those living in biomass fuel households, to develop a health promotional intervention.

Keywords: Outdoor cooking, solid biomass fuels, household air pollution, acute respiratory infection, child health.

1. Introduction

Over three billion people in resource poor settings worldwide rely on solid biomass (wood, dung, charcoal, crop residue, coal) fuels for domestic cooking, heating and lighting (WHO, 2018). Biomass fuel combustion using traditional stoves produces high levels of household air pollution (HAP); indicating the urgent need for low-cost, affordable and feasible harm-mitigation interventions. One in four deaths among children aged under five years is associated with HAP exposure, with Acute Respiratory Infections (ARI) being an attributable cause (Prüss-Ustün et al., 2016). Case reduction in ARI risks have been observed following transition from biomass to cleaner fuels (such as LPG, electricity) (Admasie et al., 2018; Rana et al., 2019), improved cook stoves (ICS) (Harris et al., 2011; Hartinger et al., 2016; Kirby et al., 2019) and, among biomass users, transitioning from wood to charcoal cooking fuels (Woolley et al., 2020).

Cooking location has the potential to reduce the level of HAP exposure, with outdoor cooking a common practice within multiple sub-Saharan Africa (SSA) countries; therefore, an intervention to further promote this behaviour may reduce the associated harms. However, to the best of our knowledge there has been no previous research into the factors predicting cooking location at national, household and individual levels; thereby providing important context to inform development of effective behavioural change interventions in terms of 'capability', 'opportunity' and 'motivation' (Michie et al., 2011). Additionally, there remains a paucity of information regarding the relative health benefits of transitioning from indoor to outdoor cooking location. Langbein *et al.* (2017) and Langbein (2017) previously argued that outdoor cooking was neglected as a HAP intervention, having identified benefits for ARI among those living in wood-cooking households using data obtained from Demographic and Health Surveys (DHS) globally. In addition to highlighting that outdoor cooking could be used alongside improved access to cleaner stoves to further effectiveness of these interventions (Langbein et al., 2017). However, there can also be variation in the type of outdoor cooking due to stove portability, type of biomass fuels used and proximity to neighbouring houses or structures. Previous research into household factors associated with solid fuel usage have identified poorer households, lower level of maternal education (Rehfuess et al., 2010) and larger families (Rehfuess et al., 2010; Sana et al., 2020) to be predictive factors.

Africa has a high burden of death (16%) due to ARIs (risk factors include: nutritional status, vaccination status and season etc.) among children under five years (WHO, 2020), along with the highest prevalence globally of outdoor cooking, with one in three households cooking outdoors on a regular basis (Langbein et al., 2017). It is also a continent dominated by low-income economies, 18 of which are fragile or conflict-affected (The World Bank, 2020). Substantial variation in prevalence of outdoor cooking can be observed between Africa, Asia and Latin America (Langbein et al., 2017), with biomass cooking characteristics, location choice and cooking behaviour differing due to cultural preferences, and also influenced by seasonality (Putti et al., 2015), wealth (Makonese et al., 2018) and geographical characteristics (Langbein et al., 2017). This study aims to address this evidence gap by investigating (i) contextual, household and individual determinants of outdoor cooking behaviours, (ii) the association between outdoor cooking practices with risk of respiratory symptoms (cough, shortness of breath, fever), ARI and severe ARI (SARI) among children aged under five years, for biomass cooking households, using comprehensive, population-based DHS data for 30 sub-Saharan African countries.

2. Material and methods

2.1. Data sources

We undertook a cross-sectional study using the most recent DHS survey conducted within the last 10 years, completed in each of the 30 SSA countries. Included countries were those with data on cooking location and inclusion of the outcome variables of interest (Appendix 1). The DHS is a publicly available dataset (DHS, 2020), routinely collected and supported by the United States Agency for International Development (USAID). USAID provides training for government agencies and health authorities to undertake the survey to collect population and health data, with some country-specific modifications to the survey. Each survey contains core questions, which have been translated into the main languages(s) required with that country, and back translated for validation. Pilot data collection within each country (approx. 100-200 households) is undertaken to check translation of questionnaire, skipping pattern of questions and confirming the interviews and supervisors manuals are suitable (ICF International, 2012). Ethical approvals are granted by the relevant government authority (Croft et al., 2018). The DHS online archive contains the anonymised data, with access authorisation being given for this study.

The data collection process involves applying standardised core questionnaires from DHS Phases VI, VII, and VIII and two-stage stratified sampling methodology, where identified clusters, based on enumeration areas, have households selected based on proportionate random sampling (details available at Croft *et al.*, 2018). Only residential households were eligible for inclusion, comprising ever-married (has been married at least once in their life) women and men aged 15-49 years resident at the household the night before the survey. Surveys included in the analysis have a response rate range of 90.7 - 99.5% for eligible women. For this current analysis data were extracted from the household, women and child DHS datasets to gain information for selected contextual, maternal and residing child characteristics. Only solid biomass cooking fuel households were included as cleaner fuels tend to be used inside.

A modified wealth index was calculated in SPSS (IBM Corp, 2020), using the DHS guide (Rutstein, 2015), as the wealth index provided contains cooking fuel as a predictor within the principle component analysis (Rutstein and Johnson, 2004). Therefore cooking fuel was removed from the new wealth index, to prevent circularity leading to an underestimation in the results (Tusting et al., 2017). The indicator variables in each country vary (appendix 2) but included house construction material (wall, roof and floor), source of drinking water, house construction material (wall, roof and floor), toilet facility, access to electricity and assets.

2.2. Predictor and Outcome Variables

All study variables are listed and described below, with appendix 3 detailing the variables which were included within each analysis.

2.2.1. Household cooking location

Cooking location information was provided from the main respondents of the household survey being asked "Is the cooking usual done in the house, in a separate building or outdoors?". Cooking location was then defined as: (a) in the house; (b) in a separate building; and (c) outdoors. For analyses contextual and household determinants of cooking location behaviour, a binary variable, defined as 'indoors' (in the house, in a separate building) or 'outdoors' was created.

2.2.2. Respiratory health outcomes

Respiratory symptoms (cough, shortness of breath and fever) were reported by the mother as those occurring in the child within two weeks prior to the interview. Composite measures for acute respiratory infection, ARI (cough, shortness of breath (Simoes et al., 2006)) and SARI (cough, shortness of breath and fever) were generated (Madhi and Klugman, 2006; WHO, 2011; Sk *et al.*, 2020). All child respiratory health outcomes were modelled as a binary variable (yes, no).

2.2.3. Explanatory variables

All covariates were modelled as categorical variables. Contextual, household and individual level variables were included in the core analysis to identify predictors of outdoor cooking behaviours and respiratory health assessment; due to their clinical and statistical relevance with the outcome. These variables included: (a) contextual factors: place of residence (rural, urban), season (dry, wet) and household at high altitude (<2500 m , ≥2500 m above sea level); (b) household factors: main cooking fuel type (coal/lignite, charcoal, wood, straw/shrubs/grass/agricultural crop/animal dung), number of household members (≤6, >6) as a proxy for crowding, smoking status (no, yes), women's empowerment (empowered, not empowered); (c) household head factors: sex (male, female), age (≤20, 21-30, 31-40, 41-50, 51-60, ≥61 years), highest education level (no education, primary school, secondary school or higher), wealth index (lowest, low, middle, high, highest). Information about season at survey date was gathered from the Central Intelligence Agency (CIA) fact book (CIA, 2019) and alternative sources, with season being assigned to a country, or where relevant, in specific countries at a regional level. Women's empowerment is a composite measure calculated at a household level, defined by the DHS, as empowerment being when women makes decisions on large household purchases, own healthcare and visits to family or relatives, either alone or jointly with husband (Croft et al., 2018). Wealth index is calculated by the DHS using component analysis based on selected household characteristics (e.g. assets and dwelling features) (Croft et al., 2018).

Maternal and individual child characteristics were included in the respiratory health assessment only. Individual child health outcomes included age (>1, 1, 3, 4, 5 years), sex (male, female), birth order (first born, not first born), birthweight (<2500 g, ≥2500 g), mode of delivery (vaginal, caesarean), ever breastfed (ever, never), received vitamin A in the last 6 months (yes, no), received iron in the last 6 months (yes, no). Maternal characteristics included highest educational level (no education, primary, secondary or higher), age (15-24, 25-35, 36-49 years). Maternal education and age were used instead of the household head variables in the respiratory health assessment (appendix 3).

2.3. Data analysis

The Multivariate Imputation by Chained Equations (MICE) package (van Buuren and Groothuis-Oudshoorn, 2011) in R studio (R Core Team, 2020) was used to impute relevant covariates where there was <50% missing at random observations (Madley-Dowd et al., 2019; Mishra and Khare, 2014) at country level with 50 iterations (Bodner, 2008; White et al., 2011). Variables that required imputing that the level of missing data within the combine dataset include: cooking location (0.6%), Mode of delivery (1.0%), Birthweight (46.8%), breastfeeding status (3.3%), Received Vitamin A in last 6 months (1.0%), Taking iron pills, sprinkles or syrup (6.5%), Mother's education level (0.02%), Cooking fuel (0.004%), Number of household members (0.1%), Household smoking (5.0%), Altitude – (26.6%). Descriptive statistics for each categorical outcome, number of cases (n), and percentage (%), were presented for the combined dataset. Logistic regression was used and hierarchical nested dataset structure accounted for with the Survey package (Lumley, 2020) in R studio, was used to test associations for both outdoor cooking and respiratory health outcomes, adjusting for confounding factors; reporting Adjusted Odds Ratios (AOR) and 95% Confidence Intervals (CI). For the respiratory health outcomes AORs and 95% CIs were calculated by country and presented in a forest plot, along with a summary statistic for the combined dataset. The following exploratory and sub-analysis were undertaken to account and explore confounding factors.

1. **Exploratory analysis 1 - household and contextual determinants analysis only:** Undertaken among those countries (n=24) which included information for household altitude (i.e., not missing or incomplete) and differentiation between specific indoor cooking locations (In the house, in a separate building)
2. **Exploratory analysis 2 - child respiratory health outcomes only:** Undertaken among those countries which included information for breastfeeding (n=18), birthweight (n=20), smoking (n=20) and altitude (n=16) variables (i.e., not missing or incomplete)
3. **Stratified sub-analysis 1 – both analyses:** investigation of rural-urban differences
4. **Stratified sub-analysis 2 – household and contextual determinants analysis only**: indoor cooking location (in the house and in a separate building), wood cooking households and geographic region (western, eastern, southern, central Africa).

3. Results

Out of the 30 included countries, the overall average prevalence of outdoor cooking in SSA was 42.0%, with the highest prevalence in Niger (80.0%) and lowest in Burundi (7.4%) (figure 1 and 2). Regionally, western Africa had the highest prevalence (52.7%) of outdoor cooking and the lowest was in East Africa (24.9%).

3.1. Contextual and household determinants of cooking location behaviour

Indoor cooking was compared to outdoor cooking in 340,334 households (table 1). A higher level of educational attainment and older age of head of household were associated with increased likelihood of indoor cooking, with increased odds ratio among those households with primary (AOR: 1.59; 95% CI: 1.54-1.65) and secondary/higher educated heads of households (AOR: 1.41; 95% CI: 1.35-1.47) compared to those with no education (table 2). Indoor cooking was least likely among those households with younger household heads (<20 years) (AOR: 0.81; 95% CI: 0.76-0.87) and most likely among those with a household head aged >60 years (AOR: 1.33; 95% CI: 1.29-1.38). Increased wealth was also associated with indoor cooking, with the highest odds ratio observed in those within the highest wealth quintiles compared to the lowest (AOR: 1.72; 95% CI: 1.61-1.83). Use of specific fuel types was also associated with cooking location choice, with indoor cooking more likely to occur among those households using agricultural biomass (straw/shrubs/grass/agricultural crop/animal dung) (AOR: 1.33; 95% CI: 1.17-1.51) and less likely among coal/lignite (AOR: 0.30; 95% CI: 0.27-0.35) or charcoal users (AOR: 0.59; 95% CI: 0.56-0.62) compared to wood fuel households. Other household and regional level factors which were predictors of indoor cooking included household with greater than six household members (AOR: 1.08; 95% CI: 1.05-1.11). However, presence of a smoker in the household (AOR: 0.95; 95% CI: 0.93-0.97), higher level of female empowerment (AOR: 0.85; 95% CI: 0.33-0.88) and interviews undertaken in the wet season (AOR: 0.73; 95% CI: 0.70-0.77) was associated with reduced odds ratio of cooking indoors.

In exploratory analysis 1 by indoor cooking location type, the same trend in wealth could be seen when comparing outdoor cooking to cooking in a separate building, however, no association was observed when comparing outdoor cooking to cooking in the house (table 2). In addition, exploratory analysis 1 where altitude was included, with 24 countries, showed an observed increase in the odds ratio (AOR: 4.43; 95% CI: 3.20-6.14) of indoor cooking among households at high elevations (>2500 m) compared to lower elevations (<2500 m) (appendix 4).

In the stratified sub-analyses 1 by rural and urban area classification, indoor cooking was associated with increasing wealth index, older household head and higher education level. However, wealth index, older household head and higher greater education level had marginally higher odds ratio of indoor cooking among households in rural compared to the corresponding urban area. Household and contextual determinants also differed between geographic locations (appendix 4), for example indoor cooking in East Africa had decreased odds ratio of primary education (AOR: 0.91; 95% CI: 0.85-0.95) compared to no education and in South Africa having a female (AOR: 1.61; 95% CI: 1.05-1.28) and younger household heads (<20 years) (AOR: 1.61; 95% CI: 1.13-2.31) decreased increased the odds of indoor cooking.

3.2. Child respiratory health outcomes

3.2.1. Respiratory symptoms

In the pooled data analysis we observed that in the two weeks prior to the survey 21.5% of all children experienced cough, 9.6% shortness of breath and 23.5% fever (table 3), with those living in outdoor cooking households being less likely to report symptoms: cough (AOR: 0.90; 95% CI: 0.86-0.95), shortness of breath (AOR: 0.91; 95% CI: 0.85-0.98) and fever (AOR: 0.85; 95% CI: 0.81-0.89) (figure 3) than households cooking in the house; and remained associated with cooking location in exploratory 2 and stratified sub-analysis 1 (table 4). However, no association was observed with shortness of breath (AOR: 0.93; 95% CI: 0.85-1.01) in rural areas with stratified sub-analysis 1 (table 4).

3.2.2. Acute Respiratory Infection (ARI) and Severe Acute Respiratory Infection (SARI)

In the pooled dataset, the overall prevalence of ARI and SARI were 8.8% and 5.3%, respectively (table 3). There were lower odds ratio of SARI (AOR: 0.87; 95% CI: 0.78-0.92) and ARI (AOR: 0.89; 95% CI: 0.83-0.95) among those cooking outdoors compared to in the house, and for cooking in the house compared to a separate building (SARI: AOR: 0.85; 95% CI: 0.78-0.92) and (ARI: AOR: 0.89; 95% CI: 0.84-0.96) respectively. At a country level outdoor compared to in the house cooking was associated with reduced risk of SARI in Burkina Faso, Mozambique, Togo and DRC (figure 3). With ARI, a reduced risk was associated with outdoor compared to in the house cooking in Gambia, Burkina Faso, Ethiopia and DRC and Cameroon (figure 3).

In exploratory analysis 2 investigating the effect of breastfeeding, birthweight, smoking or altitude, a similar pattern was observed (table 4). In the stratified sub-analysis 1 by urban and rural status, the association between cooking location and ARI (AOR: 0.90; 95% CI: 0.82-0.98) and SARI (AOR: 0.86; 95% CI: 0.77-0.95) remained within rural areas only (table 4). However, in urban areas only ARI was associated with cooking location (AOR: 0.88; 95% CI: 0.78-0.99).

4. Discussion

In this large-scale cross-sectional study, we report the contextual, household and individual determinants of outdoor household cooking location among 340,334 households (in 30 countries) and identified impacts of cooking location choice upon ARI risk among 263,948 children (in 23 countries). We report outdoor cooking in 42% of households, with reduced odds of SARI (13%), ARI (11%), cough (10%), shortness of breath (9%) and fever (15%) observed in children under five years residing in outdoor biomass cooking households compared to indoor cooking households after adjustment for a comprehensive range of confounding factors. Reductions in ARI through outdoor cooking may reduce respiratory-related morbidity and mortality in children under five years. We also identified patterns of outdoor cooking location choice which are informative for the design and targeting of future HAP intervention measures, in terms of capability, opportunity and motivation for behaviour change. The results showed households that are poorer, have a lower education level, a younger household head and a lower level of women's empowerment were more likely to cook outdoors. A decision to cook outdoors was also more likely during the dry season and at lower altitudes, and is likely to reflect the importance of contextually relevant environmental considerations.

4.1. Contextual and household determinants of cooking location choice

Understanding the modifiable and non-modifiable household and contextual determinants could inform future targeted interventions for promoting outdoor cooking behaviours, which will likely be multi-component complex interventions, including wider structural changes (Langbein et al., 2017). The household and contextual factors observed with outdoor cooking coincide with those observed with solid biomass fuel use (Rehfuess et al., 2010; Sana et al., 2020), supporting contextually driven behaviours (Rehfuess et al., 2010); especially when comparing rural-urban and geographic locational differences.

This study highlights a large variation in the country level prevalence of outdoor cooking behaviours (figure 2), throughout SSA, in part influenced by country wealth; which was also observed at a household level as an increase in wealth strongly influences cooking in a separate building, whereas, as the reverse is seen in outdoor cooking compared to in the house. However, no association was observed or confounding affect when attempting to account for the country level Gini index, a measure of income inequality. Capability and opportunity for cooking behaviours was strongly influenced by wealth, as well as, female empowerment and education, which are modifiable factors. Education has previously been shown to influence the use of cleaner fuels (Rehfuess et al., 2010) and should be made a priority within the design of interventions; with some current research actively integrating education in to HAP interventions (Alexander et al., 2018; Hengstermann et al., 2021; Nantanda et al., 2019). Although smoking is a modifiable characteristic, indoor cooking was less likely among households where smoking was present. However, within a stratified analysis of non-smoking households little difference in the overall effect size was observed, supporting that there are differing contextual factors between cooking in the house and a separate building.

The type of cooking fuel used was also an important modifiable factor, as the stratified sub-analysis 2 of just those using wood fuel for cooking little differences were observed (table 2). Although households with younger heads were more likely to cook outdoors, this could be a reflection of a generational shift in cooking behaviour. Self-reporting place of cooking at time at interview, does not necessarily reflect usual residence or long-term, year-round cooking habits, may explain differences in outdoor cooking prevalence between the findings of this study and Langbein *et al.* (2017) findings. Thus, due to the multiple confounding factors, any policy intervention to reduce HAP exposure through the use of outdoor cooking should take a holistic review of the current situational and target population characteristics.

4.2. Child respiratory health outcomes

The substantive variation in contextual setting, including cultural cooking practices, likely accounts for the range of effect sizes for the association between cooking location respiratory health outcomes by country (figure 3), despite undertaking adjustment for key confounding factors (e.g., household wealth, level of education and survey season). Furthermore, having access to electricity was of borderline significance (AOR: 0.92; 95% CI: 0.85-1.00) in reducing ARI compared to not having access to electricity; but access to electricity is influenced by wealth due to being included in the wealth index and therefore not incorporated in the final model. Cooking in a separate building may produce some respiratory-health benefit and the association remained after controlling for birthweight breastfeeding, household smoking status and altitude; but caution should be maintained in this interpretation as these sub-analyses were likely underpowered. In addition, the fact that no associations with SARI were observed within urban areas, but are present within rural areas, is suggestive of other factors within the rural-urban divide, such as co-inhabitation with livestock, water, sanitation and hygiene (WASH) provision, malnutrition (Boadi and Kuitunen, 2006; Kashima et al., 2010), choice of fuel (Esong et al., 2021) and levels of ambient air pollution in determining childhood ARI.

4.3 Implications of cooking behaviour change

Although, a few small studies have seen lower HAP levels with outdoor cooking with percentage mean reductions of area $PM_{2.5}$ ranging from 68-73% and 77-87% for PM_{10} (Albalak et al., 1999; Rosa et al., 2014; Sidhu et al., 2017; Van Vliet et al., 2013; Yamamoto et al., 2014), the levels often remain above the WHO Indoor air quality guidelines (Thomas et al., 2015) and are not low enough to be compared to the WHO exposure-response curves (WHO, 2021). There are variations in methods of outdoor cooking practices (e.g., stove type, proximity to house) and methods of HAP measurement which create variation in the published literature, thus there is need to better standardisation in the terminology and measurement locations to improve comparability to enable a holistic understanding of HAP exposure reduction in outdoor cooking. In addition, there is a knowledge gap around the potential unanticipated consequences of cooking outdoors, especially within urban areas (e.g., increase in local ambient air pollution, female safety, child burns risk etc.) and the ethical implication of such an intervention. An attempt was made to additionally adjust for influences of country level conflict, with the anticipation of a lower prevalence in outdoor cooking with higher conflict levels, but no association was observed and therefore this variable was not retained in adjusted models. Also, while cooking fuel type could be included as a confounding factor, no information was available for stove type, multiple fuel use and number of cooking periods per day or a number of other cooking-related practices e.g. cooking methods or behaviours and cultural traditions; which could impact the level of exposure (Odo et al., 2021). In addition, it is unclear if outdoor cooking reduces the level of pollutant produced; therefore the environmental impacts of air pollution would remain without cleaner alternatives (Bockarie et al., 2020). Therefore, cleaner fuel alternatives such as LPG and increased electrification using renewable energy generation should remain the longer-term solutions, and outdoor cooking as an interim harm-reduction solution to mitigate HAP exposure.

4.4 Strengths, limitations and further research

We report findings from a large sample and comparison across SSA, which reports predictors of household cooking locations and indicates respiratory benefits may be associated with location choice accounting for regional seasonality. However, the data was observational and not all potentially relevant confounding factors could be accounted for in our analyses (e.g., ambient air pollution, access to healthcare, nutritional status), which may lead to residual confounding and that reverse causality cannot be ruled out. Although, some of the uncertainty around recall bias with maternally reported respiratory symptoms (Odo et al., 2021); will be reduced by documenting symptoms that have occurred within two weeks prior interview. Further research should focus on improving the longitudinal annual characterisation of outdoor cooking patterns, with HAP exposure levels and improved ARI diagnosis, to determine an exposure-response relationship. In addition, a more detailed understanding is required of the potentially negative implications of outdoor cooking, including safety and security, potential for insect bites, comfort for household residents and impact of ambient air pollution. Further research is required to evaluate the implication and case reduction of other health outcomes such as low-birthweight, women's respiratory health, malaria etc. Although, outdoor cooking is a common practice within some SSA, further qualitative research into the enablers and barriers of outdoor cooking, to understand the capability, opportunity and motivation (Michie et al., 2011) for outdoor cooking behaviours, may increase the success of any future health promotional intervention which seeks to increase outdoor cooking behaviours.

5. Conclusion

Outdoor cooking practices has the potential to reduce respiratory infections among children compared to indoor cooking, and health promotional initiative to influence cooking behaviours must account for the household and contextual predictors of cooking location choice. In addition, greater knowledge is required with attitudes towards outdoor cooking including, enablers and barriers and unintended consequences.

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Author Contributions

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Data Avaliablity

The DHS is public available to download at https://dhsprogram.com/data/

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Tables

Table 1: Descriptive statistics for household and contextual determinants of cooking location at a household level.

	N = 340,856 (Missing = 0.15%)		
	Outdoors (N=134,961)	**Indoor (N=198,817)**	**p value**
Household head education level*			<0.001
No education	57419 (43%)	74612 (38%)	
Primary	38847 (29%)	73747 (37%)	
Secondary or Higher	37700 (28%)	49300 (25%)	
Sex of household head			<0.001
Female	35812 (27%)	53470 (27%)	
Age of household head (years)*			<0.001
>20	3013 (2%)	3325 (2%)	
21-30	27692 (21%)	35505 (18%)	
31-40	35887 (27%)	49468 (25%)	
41-50	25779 (19%)	39240 (20%)	
51-60	19979 (15%)	32479 (16%)	
60+	22603 (17%)	38791 (20%)	
Wealth Index			<0.001
Lowest	31773 (24%)	48299 (24%)	
Low	28808 (21%)	44306 (22%)	
Middle	27339 (20%)	41353 (21%)	
High	25756 (19%)	36787 (19%)	
Highest	21286 (16%)	28072 (14%)	
Number of household members*			<0.001
>6	35096 (26%)	55968 (28%)	
Household smoking*			<0.001
No	99642 (79%)	157785 (80%)	
Cooking fuel			<0.001
Coal, Lignite	3381 (3%)	1747 (1%)	
Charcoal	34552 (26%)	30986 (16%)	
Wood	94439 (70%)	160035 (80%)	
Other biomass	2590 (2%)	6049 (3%)	
Place of Residence			<0.001
Urban	47142 (35%)	42884 (22%)	
Season			<0.001
Dry	65766 (49%)	112298 (56%)	
Woman's empowerment			<0.001
No empowerment	54965 (41%)	72628 (37%)	
Altitude*			<0.001
Not High	93361 (100%)	166473 (98%)	

Missing: Household head education level – 0.6%, Age of household head – 0.005%, Number of household members – 0.06%, Household smoking – 3.14%, Altitude – 20.9%

N= number of households, % = percentage within each group, p-value = Kruskal-Wallis. Other biomass = Straw/shrubs/grass/Agricultural crop/Animal Dung

Table 2: Multilevel logistic regression for the household and contextual determinants of cooking location, showing the adjusted odds of indoor cooking (In the house, in a separate building) compared to outdoor cooking

	Any Indoors [a] (N = 340,334)		**In a separate building [b] (N = 276,424)**		**In the House [c] (N = 200,861**		**Sub-analysis Rural (N = 246,901)**		**Urban (N = 93,433)**		**Wood (N = 254,474)**	
	AOR [95% CI]	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***
Head of household's education level												
Primary	**1.59[1.54-1.65]**	**<0.001**	**1.70[1.63-1.76]**	**<0.001**	**1.39[1.32-1.45]**	**<0.001**	**1.70[1.63-1.77]**	**<0.001**	**1.22[1.14-1.30]**	**<0.001**	**1.67[1.61-1.74]**	**<0.001**
Secondary or Higher	**1.41[1.35-1.47]**	**<0.001**	**1.44[1.38-1.51]**	**<0.001**	**1.35[1.27-1.44]**	**<0.001**	**1.45[1.37-1.53]**	**<0.001**	**1.22[1.15-1.30]**	**<0.001**	**1.44[1.37-1.51]**	**<0.001**
Sex of household head												
Female	**1.05[1.02-1.08]**	**<0.001**	**1.04[1.01-1.07]**	**<0.001**	**1.05[1.01-1.09]**	**0.01**	**1.06[1.03-1.1]**	**<0.001**	**1.01[0.97-1.06]**	**0.56**	**1.06[1.03-1.09]**	**<0.001**
Age of household head (years)												
<20	**0.81[0.76-0.87]**	**<0.001**	**0.78[0.71-0.84]**	**<0.001**	**0.86[0.79-0.94]**	**<0.001**	**0.75[0.70-0.81]**	**<0.001**	**1.03[0.87-1.21]**	**0.75**	**0.77[0.71-0.83]**	**<0.001**
21-30	ref.		ref.				ref.		ref.		ref.	
31-40	**1.08[1.05-1.11]**	**<0.001**	**1.16[1.12-1.19]**	**<0.001**	0.97[0.94-1.01]	0.14	**1.09[1.06-1.13]**	**<0.001**	**1.07[1.01-1.14]**	**0.01**	**1.08[1.04-1.11]**	**<0.001**
41-50	**1.18[1.15-1.22]**	**<0.001**	**1.29[1.25-1.34]**	**<0.001**	1.02[0.98-1.07]	0.28	**1.18[1.13-1.22]**	**<0.001**	**1.22[1.14-1.29]**	**<0.001**	**1.15[1.11-1.20]**	**<0.001**
51-60	**1.25[1.21-1.30]**	**<0.001**	**1.39[1.33-1.44]**	**<0.001**	1.05[1.00-1.10]	0.06	**1.22[1.17-1.27]**	**<0.001**	**1.35[1.26-1.44]**	**<0.001**	**1.24[1.19-1.29]**	**<0.001**
60+	**1.33[1.29-1.38]**	**<0.001**	**1.46[1.40-1.52]**	**<0.001**	**1.14[1.08-1.20]**	**<0.001**	**1.27[1.21-1.32]**	**<0.001**	**1.53[1.42-1.65]**	**<0.001**	**1.31[1.25-1.36]**	**<0.001**
Wealth Index												
Lowest	ref.		ref.		ref.		ref.		ref.		ref.	
Low	**1.04[1.00-1.07]**	**0.04**	**1.27[1.22-1.32]**	**<0.001**	**0.74[0.71-0.78]**	**<0.001**	**1.05[1.02-1.09]**	**<0.001**	**0.84[0.74-0.96]**	**0.01**	**1.05[1.01-1.09]**	**0.01**
Middle	**1.13[1.08-1.17]**	**<0.001**	**1.54[1.47-1.61]**	**<0.001**	**0.61[0.57-0.64]**	**<0.001**	**1.14[1.09-1.19]**	**<0.001**	0.93[0.82-1.05]	0.25	**1.16[1.11-1.21]**	**<0.001**
High	**1.32[1.25-1.39]**	**<0.001**	**1.95[1.84-2.05]**	**<0.001**	**0.56[0.52-0.60]**	**<0.001**	**1.36[1.28-1.44]**	**<0.001**	1.04[0.92-1.17]	0.56	**1.34[1.27-1.42]**	**<0.001**
Highest	**1.72[1.61-1.83]**	**<0.001**	**2.91[2.71-3.13]**	**<0.001**	**0.61[0.56-0.67]**	**<0.001**	**1.88[1.72-2.06]**	**<0.001**	**1.32[1.16-1.49]**	**<0.001**	**1.58[1.46-1.71]**	**<0.001**
Number of household members												
>6	**1.08[1.05-1.11]**	**<0.001**	**1.15[1.12-1.18]**	**<0.001**	**0.96[0.92-1.00]**	**0.03**	**1.04[1.01-1.07]**	**0.01**	**1.18[1.13-1.23]**	**<0.001**	**1.07[1.04-1.11]**	**<0.001**
Household smoking												
Yes	**0.89[0.86-0.92]**	**<0.001**	**0.88[0.85-0.91]**	**<0.001**	**0.92[0.88-0.96]**	**<0.001**	**0.89[0.86-0.92]**	**<0.001**	**0.89[0.84-0.94]**	**<0.001**	**0.89[0.86-0.92]**	**<0.001**
Household cooking fuel												
Coal, Lignite	**0.30[0.27-0.35]**	**<0.001**	**0.21[0.18-0.25]**	**<0.001**	**0.57[0.47-0.69]**	**<0.001**	**0.23[0.18-0.29]**	**<0.001**	**0.38[0.32-0.44]**	**<0.001**	-	
Charcoal	**0.59[0.56-0.62]**	**<0.001**	**0.37[0.35-0.39]**	**<0.001**	**1.27[1.18-1.37]**	**<0.001**	**0.50[0.46-0.54]**	**<0.001**	**0.74[0.69-0.79]**	**<0.001**	-	

Wood	ref.		ref.		ref.		ref.		ref.		-	
Other biomass	**1.33[1.17-1.51]**	**<0.001**	0.92[0.80-1.05]	0.23	**2.18[1.87-2.55]**	**<0.001**	**1.32[1.15-1.51]**	**<0.001**	1.33[0.95-1.84]	0.09	-	
Place of residence												
Urban	**0.52[0.49-0.55]**	**<0.001**	**0.41[0.39-0.44]**	**<0.001**	**0.77[0.71-0.84]**	**<0.001**	**-**		**-**		**0.48[0.45-0.52]**	**<0.001**
Season												
Wet	**0.73[0.70-0.77]**	**<0.001**	**0.75[0.71-0.79]**	**<0.001**	**0.67[0.62-0.71]**	**<0.001**	**0.75[0.70-0.79]**	**<0.001**	**0.68[0.63-0.74]**	**<0.001**	**0.70[0.66-0.74]**	**<0.001**
Woman's empowerment												
Empowered	**0.85[0.83-0.88]**	**<0.001**	**0.87[0.84-0.89]**	**<0.001**	**0.84[0.80-0.87]**	**<0.001**	**0.82[0.79-0.84]**	**<0.001**	0.96[0.91-1.01]	0.08	**0.85[0.82-0.88]**	**<0.001**

a.) All: Cooking location is outdoor compared to Indoor (In the house and in a separate building).
b.) Cooking location is outdoor cooking compared to in a separate building.
c.) Cooking location is outdoor cooking compared to in the house
AOR = adjusted odds ratio, 95% CI = 95% confidence interval. *p* = p value. ref. = reference group. Numbers are calculated from outdoor compared to indoor cooking. Other biomass = Straw/shrubs/grass/agricultural crop/animal dung. N = Number of households
See appendix 3 for details of adjustment
Sub-analysis by Altitude, West, East, Central and Southern Africa are presented in Appendix 4

Table 3: Descriptive statistic on included children under five years by health outcome

	Cough (N =240,871, Missing = 8.7%)			**Shortness of breath (N = 240,698, Missing = 8.8%)**			**Fever (N =241,029, Missing = 8.7%)**			**ARI (N = 240,925, Missing = 8.7%)**			**SARI (N = 240,139, Missing = 9.0%)**		
	No (N=189,062)	Yes (N=51,809)	***p***	No (N=217,495)	Yes (N=23,203)	***p***	No (N=184,222)	Yes (N=56,807)	***p***	No (N=219,706)	Yes (N=21,219)	***p***	No (N=227,353)	Yes (N=12,786)	***p***
Cooking location [a]			<0.001			<0.001			<0.001			<0.001			<0.001
In the house	35322 (19%)	11086 (22%)		41387 (19%)	5001 (22%)		33676 (18%)	12744 (23%)		41894 (19%)	4526 (21%)		43311 (19%)	2872 (23%)	
Separate building	74105 (39%)	21266 (41%)		85796 (40%)	9490 (41%)		73186 (40%)	22249 (39%)		86814 (40%)	8584 (41%)		89920 (40%)	5055 (40%)	
Outdoors	78615 (42%)	19112 (37%)		89119 (41%)	8540 (37%)		76396 (42%)	21406 (38%)		89794 (41%)	7947 (38%)		92854 (41%)	4760 (38%)	
Sex of child			0.26			0.17			0.04			0.61			0.11
Male	95185 (50%)	26058 (50%)		109327 (50%)	11825 (51%)		92554 (50%)	28801 (51%)		110501 (50%)	10773 (51%)		114329 (50%)	6538 (51%)	
Child's age (years)			<0.001			<0.001			<0.001			<0.001			<0.001
<1	40317 (21%)	12009 (23%)		46263 (21%)	6025 (26%)		40312 (22%)	12044 (21%)		46802 (21%)	5528 (26%)		48962 (22%)	3174 (25%)	
1	36130 (19%)	12604 (24%)		42949 (20%)	5736 (25%)		34424 (19%)	14322 (25%)		43470 (20%)	5269 (25%)		45010 (20%)	3469 (27%)	
2	35936 (19%)	10428 (20%)		41793 (19%)	4546 (20%)		34532 (19%)	11871 (21%)		42235 (19%)	4141 (20%)		43636 (19%)	2552 (20%)	
3	38491 (20%)	9054 (17%)		43798 (20%)	3716 (16%)		37517 (20%)	10065 (18%)		44175 (20%)	3381 (16%)		45529 (20%)	1938 (15%)	
4	38188 (20%)	7714 (15%)		42692 (20%)	3180 (14%)		37437 (20%)	8505 (15%)		43025 (20%)	2900 (14%)		44216 (19%)	1654 (13%)	
First born			0.01			0.01			0.3			0.009			0.78
No	152334 (81%)	40660 (78%)		174459 (80%)	18410 (79%)		147643 (80%)	45502 (80%)		176218 (80%)	16817 (79%)		182148 (80%)	10216 (80%)	
Mode of delivery [a]			<0.001			<0.001			0.10			<0.001			<0.001
Caesarean	6407 (3%)	2567 (5%)		7882 (4%)	1076 (5%)		6763 (4%)	2223 (4%)		7990 (4%)	986 (5%)		8362 (4%)	578 (5%)	
Birth Weight [a]			0.51			<0.001			0.01			0.05			0.14
Low	15121 (16%)	4908 (16%)		17810 (15%)	2205 (17%)		14923 (15%)	5104 (16%)		18041 (16%)	1991 (16%)		18748 (16%)	1187 (16%)	
Breastfeeding [a]			<0.001			<0.001			<0.001			<0.001			<0.001
Never	5136 (3%)	1120 (2%)		5755 (3%)	494 (2%)		5021 (3%)	1243 (2%)		5805 (3%)	455 (2%)		5968 (3%)	286 (2%)	
Received Vitamin A in last 6 months [a]			<0.001			<0.001			<0.001			<0.001			<0.001
Yes	101120 (54%)	31747 (62%)		118725 (55%)	14041 (61%)		99286 (54%)	33687 (60%)		119950 (55%)	12938 (61%)		124406 (55%)	8004 (63%)	
Taking iron pills, sprinkles or syrup [a]			0.44			<0.001			0.44			<0.001			<0.001
Yes	24656 (14%)	6722 (14%)		28128 (14%)	3223 (15%)		23311 (14%)	8079 (15%)		28372 (14%)	3011 (15%)		29223 (14%)	2077 (18%)	
Mother's age (years)			<0.001												
15-24	52560 (28%)	15791 (30%)		61184 (28%)	7109 (31%)		51520 (28%)	16852 (30%)		61836 (28%)	6534 (31%)		64271 (28%)	3902 (31%)	
25-35	100944 (53%)	27107 (52%)		115734 (53%)	12225 (53%)		98595 (54%)	29576 (52%)		116931 (53%)	11149 (53%)		120944 (53%)	6707 (52%)	

36-49	35558 (19%)	8911 (17%)		40577 (19%)	3869 (17%)		34106 (19%)	10380 (18%)		40938 (19%)	3536 (17%)		42138 (19%)	2178 (17%)	
Mother's education level [a]			<0.001			<0.001			<0.001			<0.001			<0.001
No education	91172 (48%)	18453 (36%)		100307 (46%)	9239 (40%)		85918 (47%)	23794 (42%)		101186 (46%)	8452 (40%)		104208 (46%)	5164 (40%)	
Primary	63538 (34%)	21181 (41%)		75266 (35%)	9397 (41%)		62789 (34%)	21985 (39%)		76240 (35%)	8511 (40%)		79116 (35%)	5212 (41%)	
Secondary or Higher	34318 (18%)	12172 (23%)		41886 (19%)	4565 (20%)		35484 (19%)	11022 (19%)		42244 (19%)	4255 (20%)		43992 (19%)	2411 (19%)	
Wealth Index			<0.001			<0.001			<0.001			<0.001			<0.001
Lowest	44615 (24%)	11254 (22%)		50381 (23%)	5449 (23%)		41554 (23%)	14342 (25%)		50921 (23%)	4954 (23%)		52349 (23%)	3279 (26%)	
Low	43586 (23%)	11343 (22%)		49552 (23%)	5356 (23%)		41751 (23%)	13211 (23%)		50073 (23%)	4873 (23%)		51812 (23%)	2927 (23%)	
Middle	40116 (21%)	10793 (21%)		46017 (21%)	4858 (21%)		39130 (21%)	11816 (21%)		46477 (21%)	4444 (21%)		48128 (21%)	2624 (21%)	
High	35256 (19%)	10012 (19%)		40877 (19%)	4359 (19%)		34923 (19%)	10378 (18%)		41291 (19%)	3992 (19%)		42735 (19%)	2425 (19%)	
Highest	25488 (13%)	8405 (16%)		30668 (14%)	3182 (14%)		26865 (15%)	7059 (12%)		30945 (14%)	2957 (14%)		32329 (14%)	1531 (12%)	
Cooking fuel			<0.001			<0.001			<0.001			<0.001			0.003
Coal, Lignite	2141 (1%)	771 (1%)		2575 (1%)	337 (1%)		2384 (1%)	538 (1%)		2579 (1%)	333 (2%)		2760 (1%)	160 (1%)	
Charcoal	30928 (16%)	10574 (20%)		37288 (17%)	4197 (18%)		32124 (17%)	9449 (17%)		37615 (17%)	3902 (18%)		39303 (17%)	2191 (17%)	
Wood	151536 (80%)	39089 (75%)		172388 (79%)	18082 (78%)		145235 (79%)	45459 (80%)		174211 (79%)	16453 (78%)		179837 (79%)	10072 (79%)	
Other biomass	4450 (2%)	1372 (3%)		5234 (2%)	587 (3%)		4472 (2%)	1359 (2%)		5291 (2%)	531 (3%)		5443 (2%)	364 (3%)	
Number of household members [a]			<0.001			<0.001			<0.001			<0.001			<0.001
>6	90642 (48%)	22464 (43%)		102699 (47%)	10317 (44%)		87204 (47%)	26014 (46%)		103651 (47%)	9472 (45%)		107192 (47%)	5635 (44%)	
Household smoking [a]			0.05			0.7			0.02			0.007			<0.001
Yes	36687 (21%)	9991 (20%)		41952 (20%)	4688 (21%)		35220 (20%)	11469 (21%)		42368 (20%)	4319 (21%)		43827 (20%)	2711 (22%)	
Place of Residence			<0.001			<0.001			<0.001			<0.001			<0.001
Rural	143150 (76%)	38186 (74%)		163228 (75%)	17987 (78%)		137340 (75%)	44111 (78%)		165095 (75%)	16286 (77%)		170613 (75%)	10008 (78%)	
Season			0.21			<0.001			<0.001			<0.001			0.04
Wet	83390 (44%)	22236 (43%)		96282 (44%)	9270 (40%)		80280 (44%)	25436 (45%)		96888 (44%)	8758 (41%)		100064 (44%)	5480 (43%)	
Altitude [a]			0.001			0.27			<0.001			0.17			0.19
High	1761 (1%)	454 (1%)		1944 (1%)	271 (2%)		1873 (1%)	343 (1%)		1964 (1%)	251 (2%)		2052 (1%)	161 (2%)	

N = Number of observations. % = percentage within each group. *p* value determined through Kruskal Wallis test. Other biomass = Straw/shrubs/grass/agricultural crop/animal dung. ARI = acute respiratory infection. SARI = severe acute respiratory infection.

a.) Missing - cooking location - 0.6%, mode of delivery - 1.0%, Birthweight - 46.8%, breastfeeding status - 3.3%, received Vitamin A in last 6 months - 1.0%, taking iron pills, sprinkles or syrup - 6.5%, mother's education level - 0.02%, cooking fuel - 0.004%, number of household members - 0.1%, household smoking - 5.0%, altitude - 26.6%

Table 4: Sensitivity analysis for breastfeeding, birthweight, altitude, urban and rural areas, presenting the adjusted odds ratio of the respiratory health outcomes with outdoor cooking compared to indoor cooking.

		Cough		Shortness of breath		Fever		ARI		SARI	
		AOR [95% CI]	*p*	AOR [95% CI]	*p*	AOR [95% CI]	*p*	AOR [95% CI]	*p*	AOR [95% CI]	*p*
All countries (n=253,978)	In a separate building	**0.91[0.86-0.95]**	**<0.001**	**0.91[0.85-0.97]**	**<0.001**	**0.84[0.8-0.87]**	**<0.001**	**0.89[0.84-0.96]**	**<0.001**	**0.85[0.78-0.92]**	**<0.001**
	Outdoors	**0.90[0.86-0.95]**	**<0.001**	**0.91[0.85-0.98]**	**0.01**	**0.85[0.81-0.89]**	**<0.001**	**0.89[0.83-0.95]**	**<0.001**	**0.87[0.80-0.94]**	**<0.001**
Countries with breastfeeding (n=209,583)	In a separate building	**0.92[0.87-0.97]**	**<0.001**	**0.93[0.87-1.00]**	**0.05**	**0.84[0.8-0.88]**	**<0.001**	**0.91[0.85-0.99]**	**0.02**	**0.87[0.79-0.95]**	**<0.001**
	Outdoors	**0.91[0.86-0.96]**	**<0.001**	**0.92[0.85-0.99]**	**0.03**	**0.84[0.8-0.88]**	**<0.001**	**0.89[0.83-0.97]**	**0.01**	**0.88[0.80-0.96]**	**0.01**
Countries with birthweight (n=183,924)	In a separate building	**0.86[0.81-0.90]**	**<0.001**	**0.85[0.80-0.92]**	**<0.001**	0.87[0.83- 0.91]	<0.001	**0.85[0.78-0.91]**	**<0.001**	**0.80[0.73-0.87]**	**<0.001**
	Outdoors	**0.87[0.82-0.92]**	**<0.001**	**0.87[0.81-0.94]**	**<0.001**	0.89[0.85- 0.93]	<0.001	**0.84[0.80-0.89]**	**<0.001**	**0.84[0.76-0.92]**	**<0.001**
Countries with altitude (n=178,334)	In a separate building	**0.86[0.82-0.91]**	**<0.001**	**0.89[0.83-0.95]**	**<0.001**	**0.84[0.8-0.88]**	**<0.001**	**0.87[0.81-0.93]**	**<0.001**	**0.84[0.77-0.91]**	**<0.001**
	Outdoors	**0.89[0.85-0.94]**	**<0.001**	**0.89[0.82-0.95]**	**<0.001**	**0.84[0.8-0.89]**	**<0.001**	**0.85[0.79-0.92]**	**<0.001**	**0.85[0.78-0.94]**	**<0.001**
Countries with smoking (n=231,608)	In a separate building	**0.89[0.84-0.93]**	**<0.001**	**0.89[0.84-0.95]**	**<0.001**	**0.84[0.80-0.88]**	**<0.001**	**0.88[0.82-0.94]**	**<0.001**	**0.83[0.77-0.90]**	**<0.001**
	Outdoors	**0.90[0.86-0.95]**	**<0.001**	**0.90[0.84-0.97]**	**<0.001**	**0.85[0.81-0.88]**	**<0.001**	**0.87[0.81-0.94]**	**<0.001**	**0.86[0.79-0.93]**	**<0.001**
Countries with all confounders (n=92,608)	In a separate building	**0.82[0.77-0.88]**	**<0.001**	**0.85[0.78-0.92]**	**<0.001**	**0.85[0.8-0.91]**	**<0.001**	**0.84[0.76-0.92]**	**<0.001**	**0.81[0.73-0.91]**	**<0.001**
	Outdoors	**0.83[0.77-0.89]**	**<0.001**	**0.85[0.77-0.94]**	**<0.001**	**0.83[0.77-0.89]**	**<0.001**	**0.82[0.74-0.92]**	**<0.001**	**0.86[0.76-0.97]**	**0.02**
Urban (n=62,599)	In a separate building	**0.87[0.79-0.95]**	**<0.001**	0.89[0.79-1.01]	0.08	**0.81[0.74-0.88]**	**<0.001**	0.90[0.79-1.02]	0.09	0.88[0.75-1.03]	0.12
	Outdoors	**0.90[0.82-0.98]**	**0.01**	**0.89[0.79-0.99]**	**0.04**	**0.81[0.75-0.88]**	**<0.001**	**0.88[0.78-0.99]**	**0.04**	0.90[0.78-1.04]	0.16
Rural (n=191,379)	In a separate building	**0.92[0.87-0.98]**	**0.01**	**0.92[0.85-0.99]**	**0.04**	**0.84[0.79-0.88]**	**<0.001**	**0.90[0.83-0.98]**	**0.01**	**0.83[0.76-0.92]**	**<0.001**
	Outdoors	**0.91[0.85-0.97]**	**<0.001**	0.93[0.85-1.01]	0.09	**0.86[0.81-0.91]**	**<0.001**	**0.90[0.82-0.98]**	**0.02**	**0.86[0.77-0.95]**	**<0.001**

AOR = adjusted odds ratio, 95% CI = 95% confidence interval. n= number of children included in analysis. *p* = *p* value. ARI = acute respiratory infection. SARI = severe acute respiratory infection.
Adjusted for: Child's age, child's sex, birth order, mode of delivery, Iron supplementation, mother's education level, mother's age, woman's empowerment, wealth, cooking fuel, number of household members, households smoking, region of residence, season, country

Figures

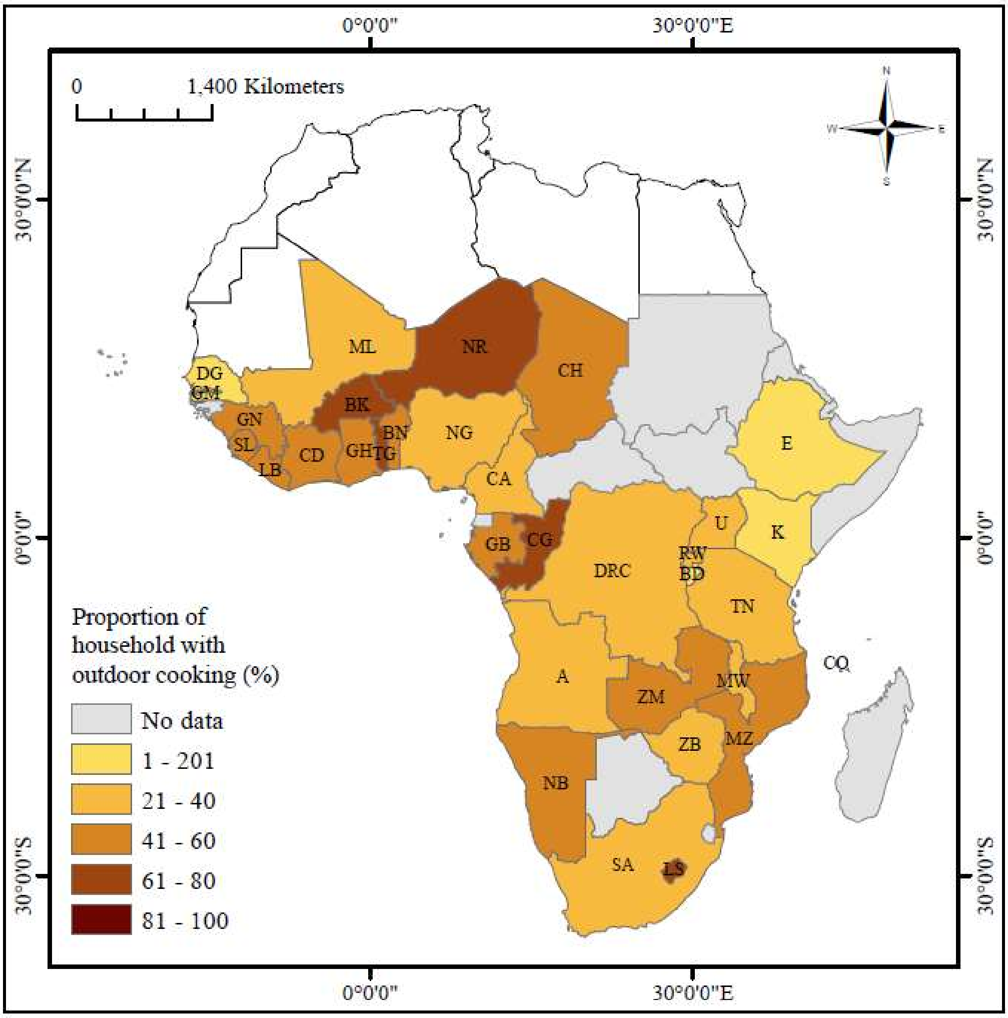


Figure 1: Geographical distribution of percentage of household outdoor cooking by country. Key: A = Angola, BN = Benin, BK = Burkina Faso, BD = Burundi, CA = Cameroon, CH = Chad, CO = Comoros, CG = Congo, DRC = Congo DRC, CD = Côte d'Ivoire, E = Ethiopia, GB = Gabon, GM = Gambia, GH = Ghana, GN = Guinea, K = Kenya, LS = Lesotho, LB = Liberia, MW = Malawi, ML = Mali, MZ = Mozambique, NB = Namibia, NR = Niger, NG = Nigeria, RW = Rwanda, DG = Senegal, SL = Sierra Leone, SA = South Africa, TN = Tanzania, TG = Togo, U = Uganda, ZM = Zambia and ZB = Zimbabwe.

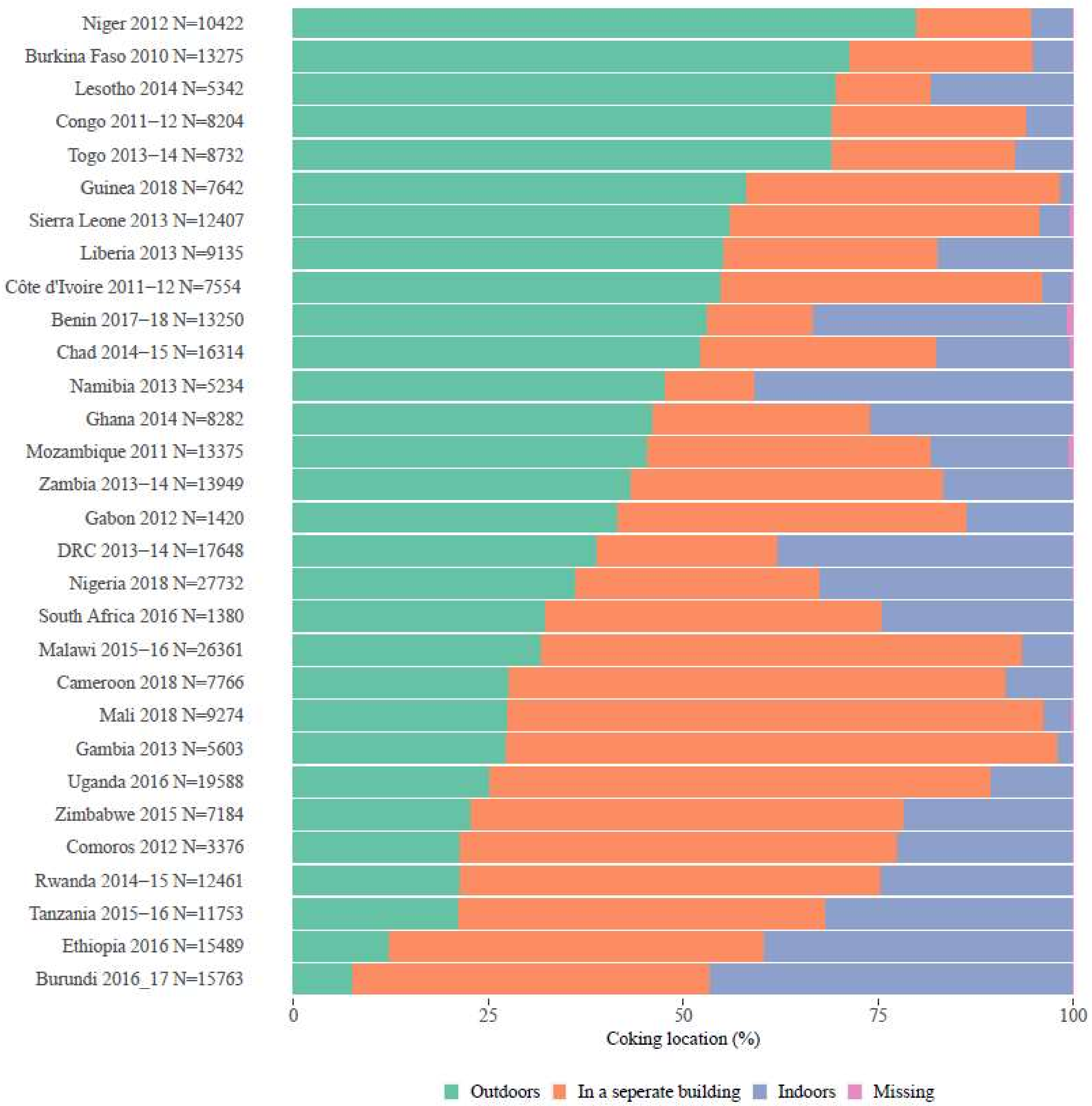


Figure 2: Proportion of households cooking outdoors, in a separate building and in the house by country. Countries with survey undertaken in: wet season only = Congo, Mali, Sierra Leone; dry season only = Gabon, Gambia, Namibia, Togo, South Africa.

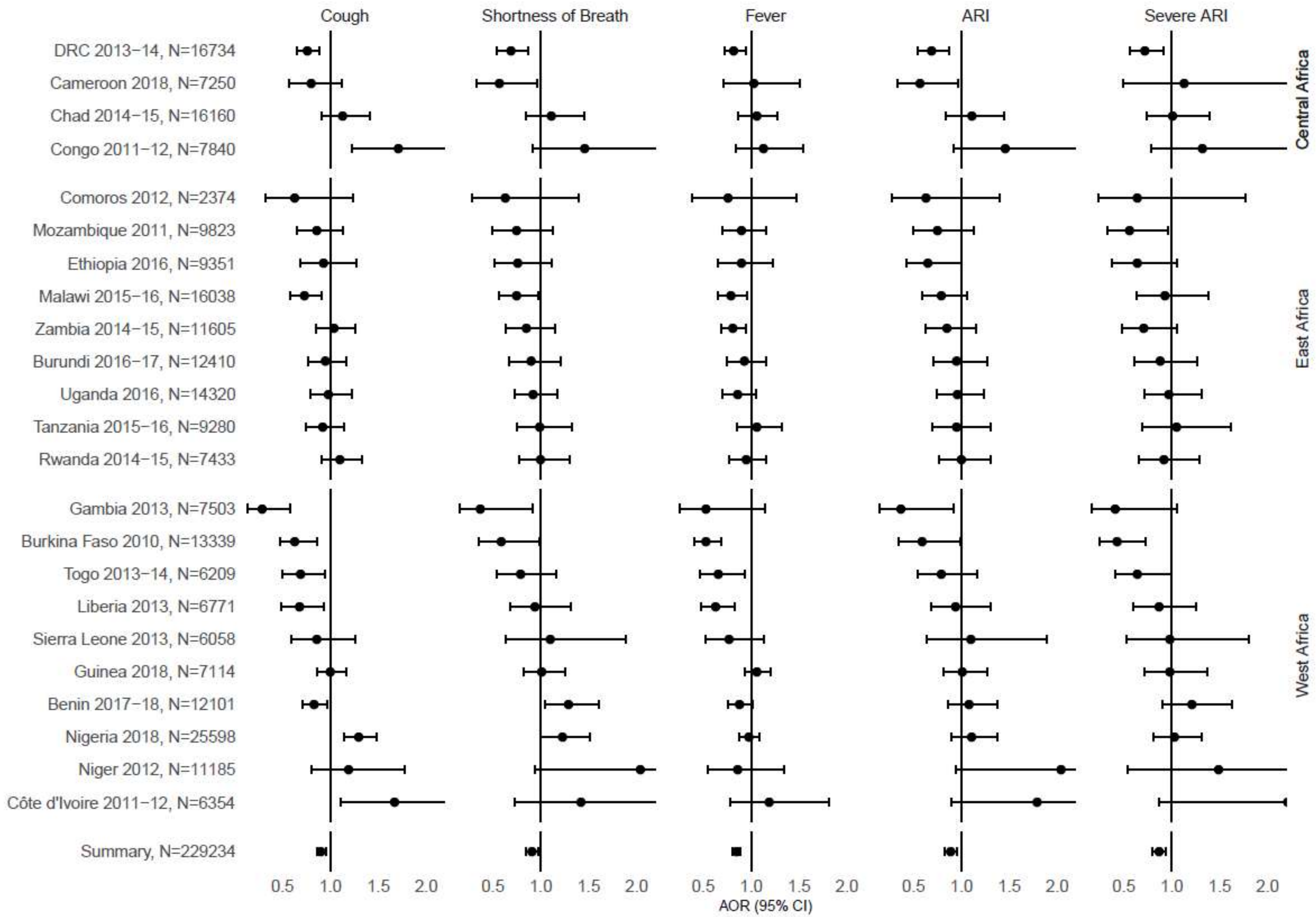
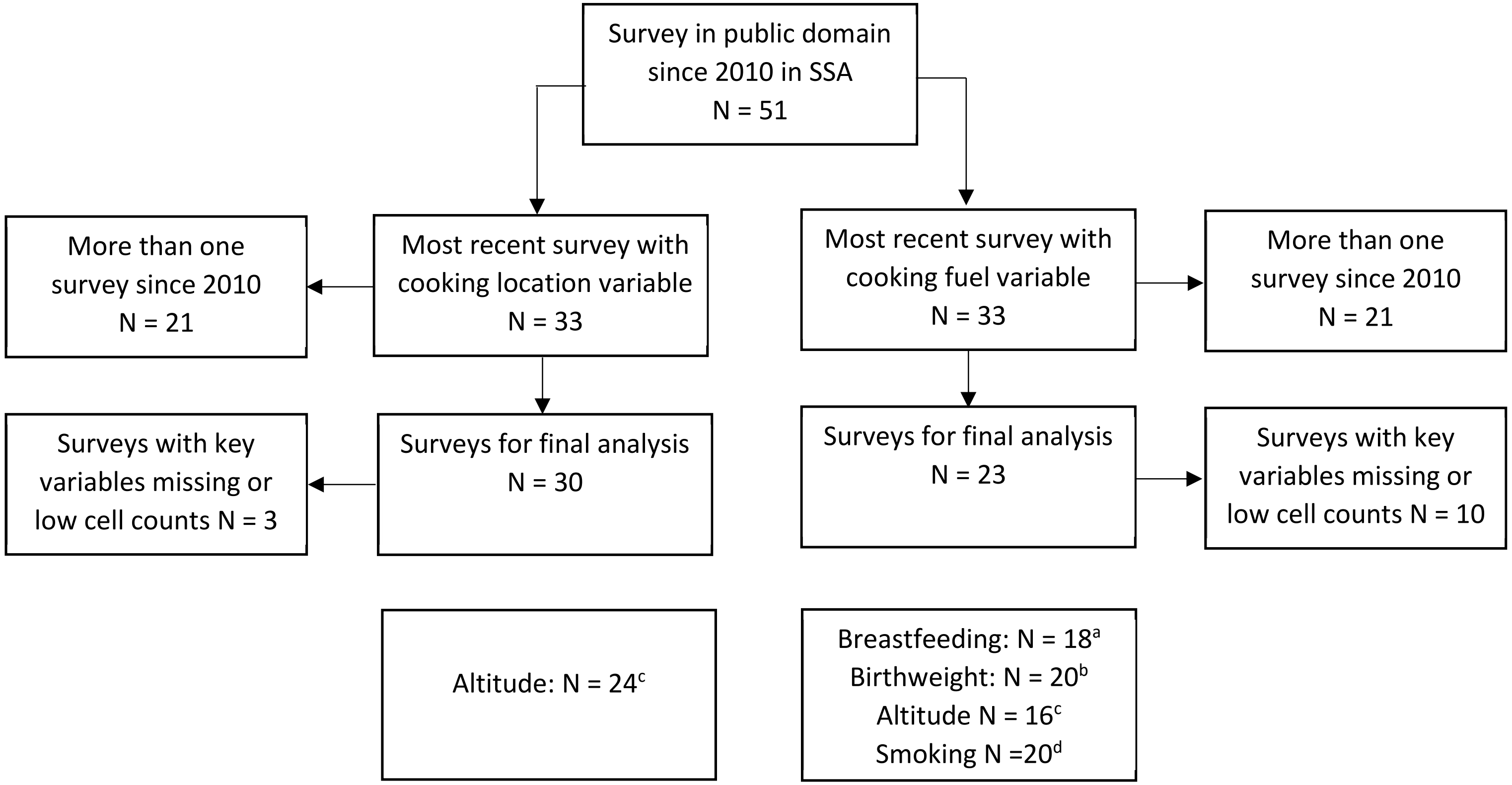


Figure 3: Forest plot illustrating the adjusted odds ratio of respiratory health outcomes with outdoor cooking compared to cooking in the house, for each included survey. Details of adjustment in appendix 3 and table of numbers in Appendix 5.

Appendix



Appendix 1: Inclusion and exclusion of dataset available for the DHS program website (DHS, 2020).

- **a.)** Breastfeeding data not available for: Gambia, Mozambique, Tanzania, Togo, Zambia
- **b.)** Birthweight data was not available for: Guinea, Niger, Sierra Leone
- **c.)** Altitude data was not available for: Chad, Comoros, Burkina Faso, Congo, Gambia, Niger and Sierra Leone.
- **d.)** Smoking data was not available for: Peru, Philippines and Kenya

Appendix 4: Indicator variables included in the modified wealth index by country

			House construction			Assets																						
Country	Source of drinking water	Toilet facility	Wall material	Roof material	Floor material	Electricity	Radio	Television	Refrigerator	watch	Bicycle	Motorcycle or scooter	Animal-drawn cart	Car or Truck	Boat with a motor	Bank account	Mobile telephone	Computer	Non-motorised boat or canoe	Tractor	Plough	Household furniture*	Household electronics*	Other assets*	Dwelling window material	Lighting fuel	Refuse collection	Own or rent house/type of dwelling
Benin 2017-18	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■				■	
Burkina Faso 2010	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■										
Burundi 2016-17	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■						
Cameroon 2018	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■	■	■				
Chad 2014-15	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■	■				
Comoros 2012	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■										
Congo 2011-12	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■						
Côte d'Ivoire 2011-12	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
DRC 2014-15	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■					■
Ethiopia 2016	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■						
Gambia 2013	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■	■					
Ghana 2014	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■					
Guinea 2018	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■					
Kenya 2014	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■					
Lesotho 2014	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■					
Liberia 2013	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■				■		
Malawi 2015-16	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■						

Mali 2018																												
Mozambique 2011																												
Namibia 2013																												
Niger 2012																												
Nigeria 2018																												
Rwanda 2014-15																												
Sierra Leone 2013																												
South Africa 2016																												
Tanzania 2015-16																												
Togo 2013-14																												
Uganda 2016																												
Zambia 2013-14																												
Zimbabwe 2015																												

*Household furniture (e.g., table, chairs, wardrobe, bed, mattress, lamps, clock)

*Household electronics (e.g., washing machine, DVD player, internet, modem/router, satellite, laptop, Generator, music system, sewing machine, fan, air conditioning, solar panel, water pump, battery, iron, TV5 antenna, Cable subscription, camera, blender, microwave)

*Other assets (e.g. Grain mill, hammer mill, Rickshaw/chingchi/Tuk tuk/htawlargyi/Keke Napep/Bagag, bank account with another institution, credit union, beneficiary of Pantawid Pamilyan Pilipino Program (4Ps), canoe with motor, banana boat, thresher, bedroom available for sleep, floor area of house)

Appendix 3: Details of variables included within each analysis.

Analysis	Outcome variable	Exposure assessment	Covariates
Household and contextual determinants	Cooking location (Indoor, Outdoor)	N/A	• Household head education level • Sex of household head • Age of household head • Wealth index • Number of household members • Household smoking • Cooking fuel • Place of residence • Season • Woman empowerment • Altitude
Respiratory Health outcomes	Cough, shortness of breath, fever, ARI or SARI (yes, no)	Cooking location (Indoor, In a separate building, outdoor)	• Child's age • Child's sex • Birth order • Mode of delivery • Breastfeeding • Birthweight • Iron supplementation • Mother's education level • Mother's age • Woman's empowerment • Wealth • Cooking fuel • Number of household members • Households smoking • Regions of residence • Season • Altitude

[a] Covariates included and chosen as confounding variables [b] Included where available
ARI = acute respiratory infection. SARI = severe acute respiratory infection.

Appendix 4: Sub-analysis result with adjustment of high altitude areas and by geographical region within SSA for the household and contextual determinants for cooking location showing the odds ratio of indoor (in the house and in a separate building) cooking compared to outdoor cooking

	Altitude (N = 272,638)		**East (N = 13,6018)**		**South (N = 13,074)**		**West (N = 13,5794)**		**Central (N = 55,448)**	
	AOR [95% CI]	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***	**AOR [95% CI]**	***p***
Head of household's education level										
Primary	**1.20[1.15-1.24]**	**<0.001**	**0.90[0.85-0.95]**	**<0.001**	1.01[0.89-1.13]	0.93	**1.31[1.25-1.37]**	**<0.001**	**1.49[1.36-1.63]**	**<0.001**
Secondary or Higher	1.05[1.00-1.10]	0.03	0.86[0.80-0.93]	<0.001	1.09[0.94-1.26]	0.25	**1.71[1.62-1.80]**	**<0.001**	**1.39[1.24-1.55]**	**<0.001**
Sex of household head										
Female	0.98[0.95-1.01]	0.15	**0.84[0.81-0.87]**	**<0.001**	**1.16[1.05-1.28]**	**<0.001**	**1.06[1.02-1.11]**	**0.01**	1.02[0.95-1.10]	0.62
Age of household head (years)										
<20	**0.86[0.79-0.94]**	**<0.001**	**0.79[0.70-0.89]**	**<0.001**	**1.61[1.13-2.31]**	**0.01**	**0.86[0.76-0.96]**	**0.01**	0.88[0.74-1.04]	0.14
21-30	ref.		ref.		ref.		ref.		ref.	
31-40	**1.06[1.03-1.09]**	**<0.001**	**1.16[1.11-1.22]**	**<0.001**	**1.24[1.05-1.46]**	**0.01**	**1.10[1.05-1.15]**	**<0.001**	0.97[0.91-1.04]	0.35
41-50	**1.17[1.12-1.21]**	**<0.001**	**1.37[1.29-1.44]**	**<0.001**	**1.69[1.42-2.00]**	**<0.001**	**1.20[1.15-1.26]**	**<0.001**	1.07[0.99-1.15]	0.08
51-60	**1.21[1.16-1.26]**	**<0.001**	**1.53[1.44-1.62]**	**<0.001**	**1.51[1.26-1.82]**	**<0.001**	**1.28[1.21-1.34]**	**<0.001**	**1.23[1.12-1.34]**	**<0.001**
60+	**1.25[1.20-1.31]**	**<0.001**	**1.48[1.40-1.58]**	**<0.001**	**2.12[1.76-2.55]**	**<0.001**	**1.39[1.32-1.47]**	**<0.001**	**1.51[1.37-1.65]**	**<0.001**
Wealth Index										
Lowest	ref.		ref.		ref.		ref.		ref.	
Low	**1.10[1.06-1.14]**	**<0.001**	**1.19[1.13-1.26]**	**<0.001**	**0.60[0.52-0.69]**	**<0.001**	1.02[0.96-1.08]	0.54	0.93[0.85-1.02]	0.13
Middle	**1.27[1.21-1.33]**	**<0.001**	**1.36[1.27-1.45]**	**<0.001**	**0.51[0.43-0.60]**	**<0.001**	1.02[0.95-1.09]	0.64	0.92[0.82-1.02]	0.12
High	**1.59[1.50-1.68]**	**<0.001**	**1.59[1.47-1.72]**	**<0.001**	**0.49[0.40-0.60]**	**<0.001**	1.02[0.94-1.10]	0.6	1.07[0.93-1.24]	0.34
Highest	**2.25[2.10-2.42]**	**<0.001**	**2.15[1.95-2.37]**	**<0.001**	**0.56[0.39-0.79]**	**<0.001**	1.10[1.00-1.21]	0.05	**1.48[1.25-1.75]**	**<0.001**
Number of household members										
>6	**1.11[1.07-1.14]**	**<0.001**	**1.20[1.14-1.25]**	**<0.001**	**1.45[1.30-1.61]**	**<0.001**	**1.15[1.11-1.19]**	**<0.001**	**1.12[1.06-1.20]**	**<0.001**
Household smoking										
Yes	**0.91[0.88-0.94]**	**<0.001**	**0.90[0.86-0.94]**	**<0.001**	**0.80[0.71-0.90]**	**<0.001**	**0.84[0.80-0.87]**	**<0.001**	1.03[0.96-1.11]	0.4
Household cooking fuel										
Coal, Lignite	**0.26[0.23-0.30]**	**<0.001**	**0.39[0.29-0.53]**	**<0.001**	**13.31[5.91-30.00]**	**<0.001**	**0.41[0.36-0.47]**	**<0.001**	0.84[0.47-1.49]	0.54
Charcoal	**0.51[0.48-0.54]**	**<0.001**	**0.44[0.41-0.48]**	**<0.001**	0.83[0.41-1.70]	0.61	**0.76[0.71-0.82]**	**<0.001**	**0.57[0.48-0.67]**	**<0.001**

Wood	ref.		ref.		ref.		ref.		ref.	
Other biomass	**1.26[1.11-1.45]**	**<0.001**	**1.72[1.45-2.05]**	**<0.001**	**1.54[1.19-1.98]**	**<0.001**	0.83[0.67-1.02]	0.08	**1.64[1.03-2.61]**	**0.04**
Place of residence										
Urban	**0.48[0.45-0.51]**	**<0.001**	0.41[0.38-0.46]	<0.001	0.38[0.29-0.5]	<0.001	0.88[0.81-0.95]	<0.001	0.5[0.42-0.59]	<0.001
Season										
Wet	**0.89[0.85-0.94]**	**<0.001**	**0.73[0.68-0.79]**	**<0.001**	**0.32[0.26-0.38]**	**<0.001**	**0.95[0.89-1.02]**	0.19	**0.64[0.56-0.73]**	**<0.001**
Woman's empowerment										
Empowered	1.02[0.99-1.06]	0.13	**0.95[0.91-0.99]**	**0.01**	1.12[0.97-1.29]	0.12	**1.06[1.01-1.10]**	**0.01**	1.05[0.98-1.12]	0.17
High Altitude										
High Altitude (<2500 m)	**4.43[3.20-6.14]**	**<0.001**	**-**		**-**		**-**		**-**	

AOR = adjusted odds ratio, 95% CI: 95% confidence interval, ref. = reference group. Other biomass - Straw/shrubs/grass/agricultural crop/animal dung, N = number of households

Appendix 5: Results used in forest plot, showing the odds ratio of each respiratory health outcome with outdoor cooking compared to cooking in the house (refer to appendix 1 for included variables).

	Cough		**Shortness of breath**		**Fever**		**ARI**		**SARI**	
Survey	**AOR [95% CI]**	***p* value**	**AOR [95% CI]**	***p* value**	**AOR [95% CI]**	***p* value**	**AOR [95% CI]**	***p* value**	**AOR [95% CI]**	***p* value**
Côte d'Ivoire 2011-12, N=6354	1.67[1.11-2.53]	0.02	1.42[0.73-2.80]	0.30	1.19[0.78-1.81]	0.42	1.79[0.90-3.56]	0.10	2.21[0.87-5.63]	0.10
Niger 2012, N=11185	1.19[0.80-1.77]	0.39	2.04[0.94-4.43]	0.07	0.86[0.55-1.35]	0.52	2.04[0.94-4.43]	0.07	1.49[0.54-4.08]	0.44
Congo 2011-12, N=7840	**1.71[1.22-2.40]**	**<0.001**	1.46[0.92-2.31]	0.11	1.13[0.84-1.54]	0.42	1.46[0.92-2.31]	0.11	1.32[0.78-2.22]	0.30
Benin 2017-18, N=12101	**0.83[0.71-0.97]**	**0.02**	**1.29[1.04-1.61]**	**0.02**	0.88[0.76-1.02]	0.10	1.08[0.86-1.37]	0.50	1.21[0.90-1.63]	0.21
Cameroon 2018, N=7250	0.80[0.57-1.12]	0.19	**0.57[0.33-0.96]**	**0.04**	1.03[0.71-1.51]	0.87	**0.57[0.33-0.96]**	**0.04**	1.13[0.49-2.64]	0.77
Tanzania 2015-16, N=9280	0.92[0.75-1.14]	0.45	0.99[0.75-1.33]	0.97	1.06[0.85-1.32]	0.61	0.95[0.70-1.30]	0.76	1.05[0.69-1.62]	0.81
Nigeria 2018, N=25598	**1.30[1.14-1.50]**	**<0.001**	1.23[1.00-1.52]	0.06	0.98[0.88-1.08]	0.67	1.11[0.90-1.38]	0.36	1.03[0.80-1.32]	0.83
Chad 2014-15, N=16160	1.13[0.91-1.41]	0.25	1.11[0.84-1.45]	0.46	1.06[0.87-1.28]	0.57	1.11[0.84-1.45]	0.46	1.01[0.74-1.39]	0.95
Sierra Leone 2013, N=6058	0.86[0.59-1.26]	0.43	1.10[0.64-1.89]	0.72	0.77[0.52-1.13]	0.18	1.10[0.64-1.89]	0.72	0.98[0.53-1.81]	0.95
Guinea 2018, N=7114	1.00[0.86-1.17]	0.96	1.01[0.82-1.25]	0.89	1.06[0.93-1.21]	0.41	1.01[0.81-1.27]	0.91	0.98[0.71-1.37]	0.92
Uganda 2016, N=14320	0.98[0.79-1.23]	0.89	0.92[0.73-1.17]	0.50	0.86[0.70-1.05]	0.14	0.96[0.74-1.24]	0.76	0.97[0.72-1.31]	0.86
Malawi 2015-16, N=16038	**0.73[0.58-0.91]**	**<0.001**	**0.75[0.57-0.98]**	**0.04**	**0.79[0.65-0.96]**	**0.02**	0.79[0.59-1.06]	0.11	0.93[0.63-1.38]	0.72
Rwanda 2014-15, N=7433	1.10[0.91-1.33]	0.32	1.00[0.77-1.30]	0.98	0.95[0.77-1.16]	0.59	1.00[0.77-1.30]	0.98	0.92[0.66-1.29]	0.63
Burundi 2016-17, N=12410	0.95[0.77-1.17]	0.61	0.90[0.67-1.21]	0.49	0.93[0.75-1.16]	0.51	0.95[0.71-1.27]	0.74	0.88[0.61-1.27]	0.49
Liberia 2013, N=6771	**0.68[0.49-0.93]**	**0.02**	0.94[0.68-1.31]	0.73	**0.63[0.48-0.83]**	**<0.001**	0.94[0.68-1.31]	0.73	0.87[0.60-1.25]	0.45
Zambia 2014-15, N=11605	1.04[0.85-1.26]	0.73	0.85[0.63-1.15]	0.29	**0.81[0.69-0.95]**	**0.01**	0.85[0.63-1.15]	0.29	0.71[0.48-1.05]	0.08
DRC 2013-14, N=16734	**0.76[0.65-0.89]**	**<0.001**	**0.69[0.54-0.87]**	**<0.001**	**0.82[0.72-0.95]**	**0.01**	**0.69[0.54-0.87]**	**<0.001**	**0.72[0.56-0.92]**	**0.01**
Comoros 2012, N=2374	0.63[0.32-1.24]	0.18	0.63[0.28-1.40]	0.26	0.76[0.39-1.47]	0.41	0.63[0.28-1.40]	0.26	0.64[0.23-1.77]	0.39
Ethiopia 2016, N=9351	0.93[0.69-1.27]	0.66	0.76[0.52-1.11]	0.16	0.90[0.65-1.23]	0.50	**0.65[0.43-1.00]**	**0.05**	0.64[0.38-1.06]	0.08
Togo 2013-14, N=6209	**0.69[0.50-0.94]**	**0.02**	0.79[0.54-1.16]	0.24	**0.66[0.47-0.94]**	**0.02**	0.79[0.54-1.16]	0.24	**0.64[0.41-1.00]**	**0.05**
Mozambique 2011, N=9823	0.86[0.65-1.13]	0.27	0.75[0.50-1.13]	0.17	0.90[0.70-1.16]	0.42	0.75[0.50-1.13]	0.17	**0.56[0.33-0.96]**	**0.04**
Burkina Faso 2010, N=13339	**0.63[0.47-0.86]**	**<0.001**	**0.59[0.35-0.99]**	**0.05**	**0.53[0.41-0.69]**	**<0.001**	**0.59[0.35-0.99]**	**0.05**	**0.43[0.25-0.73]**	**<0.001**
Gambia 2013, N=7503	**0.29[0.14-0.58]**	**<0.001**	**0.37[0.15-0.92]**	**0.03**	0.53[0.25-1.15]	0.11	**0.37[0.15-0.92]**	**0.03**	0.41[0.16-1.06]	0.07

AOR = adjusted odds ratio, 95% CI = 95% confidence interval, N= number of child observations. ARI = acute respiratory infection. SARI = severe acute respiratory infection.