

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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1 Association of household cooking location behaviour with acute respiratory
2 infections among children aged under five years; a cross sectional analysis of
3 30 Sub-Saharan African Demographic and Health Surveys

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25 Abstract

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

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

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

42 **Results:** After adjustment, outdoor cooking was more likely among households with lower wealth
43 index, younger and lower educated household heads, fewer household members, cooking fuel type
44 (charcoal, coal), empowered females, urban place of residence, wet season, compared to indoor.
45 Reduced odds ratios of SARI (AOR:0.87[0.80-0.94]), ARI (AOR:0.89[0.83-0.95]), cough
46 (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])
47 were observed among children residing in outdoor compared to cooking in the house. In rural areas
48 only outdoor cooking was associated with reduced odds ratios of cough (AOR:0.89[0.82,0.95]), fever
49 (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
50 areas cough (AOR:0.90[0.82-0.98]), shortness of breath (AOR:0.89[0.79-0.99]), fever (AOR:
51 0.81[0.75-0.88]) and ARI (AOR:0.88[0.78-0.99]) were associated with outdoor cooking.

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

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

59 1. Introduction

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

70 Cooking location has the potential to reduce the level of HAP exposure, with outdoor cooking a
71 common practice within multiple sub-Saharan Africa (SSA) countries; therefore, an intervention to
72 further promote this behaviour may reduce the associated harms. However, to the best of our
73 knowledge there has been no previous research into the factors predicting cooking location at
74 national, household and individual levels; thereby providing important context to inform
75 development of effective behavioural change interventions in terms of ‘capability’, ‘opportunity’ and
76 ‘motivation’ (Michie et al., 2011). Additionally, there remains a paucity of information regarding the
77 relative health benefits of transitioning from indoor to outdoor cooking location. Langbein *et al.*
78 (2017) and Langbein (2017) previously argued that outdoor cooking was neglected as a HAP
79 intervention, having identified benefits for ARI among those living in wood-cooking households using
80 data obtained from Demographic and Health Surveys (DHS) globally. In addition to highlighting that
81 outdoor cooking could be used alongside improved access to cleaner stoves to further effectiveness
82 of these interventions (Langbein et al., 2017). However, there can also be variation in the type of
83 outdoor cooking due to stove portability, type of biomass fuels used and proximity to neighbouring
84 houses or structures. Previous research into household factors associated with solid fuel usage have
85 identified poorer households, lower level of maternal education (Rehfuess et al., 2010) and larger
86 families (Rehfuess et al., 2010; Sana et al., 2020) to be predictive factors.

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

101 2. Material and methods

102 2.1. Data sources

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

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

126 A modified wealth index was calculated in SPSS (IBM Corp, 2020), using the DHS guide (Rutstein,
127 2015), as the wealth index provided contains cooking fuel as a predictor within the principle
128 component analysis (Rutstein and Johnson, 2004). Therefore cooking fuel was removed from the
129 new wealth index, to prevent circularity leading to an underestimation in the results (Tusting et al.,
130 2017). The indicator variables in each country vary (appendix 2) but included house construction
131 material (wall, roof and floor), source of drinking water, house construction material (wall, roof and
132 floor), toilet facility, access to electricity and assets.

133 2.2. Predictor and Outcome Variables

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

136 2.2.1. Household cooking location

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

142 2.2.2. Respiratory health outcomes

143 Respiratory symptoms (cough, shortness of breath and fever) were reported by the mother as those
144 occurring in the child within two weeks prior to the interview. Composite measures for acute
145 respiratory infection, ARI (cough, shortness of breath (Simoes et al., 2006)) and SARI (cough,

146 shortness of breath and fever) were generated (Madhi and Klugman, 2006; WHO, 2011; Sk *et al.*,
147 2020). All child respiratory health outcomes were modelled as a binary variable (yes, no).

148 2.2.3. Explanatory variables

149 All covariates were modelled as categorical variables. Contextual, household and individual level
150 variables were included in the core analysis to identify predictors of outdoor cooking behaviours and
151 respiratory health assessment; due to their clinical and statistical relevance with the outcome. These
152 variables included: (a) contextual factors: place of residence (rural, urban), season (dry, wet) and
153 household at high altitude (<2500 m , ≥2500 m above sea level); (b) household factors: main cooking
154 fuel type (coal/lignite, charcoal, wood, straw/shrubs/grass/agricultural crop/animal dung), number
155 of household members (≤6, >6) as a proxy for crowding, smoking status (no, yes), women's
156 empowerment (empowered, not empowered); (c) household head factors: sex (male, female), age
157 (≤20, 21-30, 31-40, 41-50, 51-60, ≥61 years), highest education level (no education, primary school,
158 secondary school or higher), wealth index (lowest, low, middle, high, highest). Information about
159 season at survey date was gathered from the Central Intelligence Agency (CIA) fact book (CIA, 2019)
160 and alternative sources, with season being assigned to a country, or where relevant, in specific
161 countries at a regional level. Women's empowerment is a composite measure calculated at a
162 household level, defined by the DHS, as empowerment being when women makes decisions on large
163 household purchases, own healthcare and visits to family or relatives, either alone or jointly with
164 husband (Croft *et al.*, 2018). Wealth index is calculated by the DHS using component analysis based
165 on selected household characteristics (e.g. assets and dwelling features) (Croft *et al.*, 2018).

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

174 2.3. Data analysis

175 The Multivariate Imputation by Chained Equations (MICE) package (van Buuren and Groothuis-
176 Oudshoorn, 2011) in R studio (R Core Team, 2020) was used to impute relevant covariates where
177 there was <50% missing at random observations (Madley-Dowd *et al.*, 2019; Mishra and Khare,
178 2014) at country level with 50 iterations (Bodner, 2008; White *et al.*, 2011). Variables that required
179 imputing that the level of missing data within the combine dataset include: cooking location (0.6%),
180 Mode of delivery (1.0%), Birthweight (46.8%), breastfeeding status (3.3%), Received Vitamin A in last
181 6 months (1.0%), Taking iron pills, sprinkles or syrup (6.5%), Mother's education level (0.02%),
182 Cooking fuel (0.004%), Number of household members (0.1%), Household smoking (5.0%), Altitude –
183 (26.6%). Descriptive statistics for each categorical outcome, number of cases (n), and percentage
184 (%), were presented for the combined dataset. Logistic regression was used and hierarchical nested
185 dataset structure accounted for with the Survey package (Lumley, 2020) in R studio, was used to test
186 associations for both outdoor cooking and respiratory health outcomes, adjusting for confounding
187 factors; reporting Adjusted Odds Ratios (AOR) and 95% Confidence Intervals (CI). For the respiratory
188 health outcomes AORs and 95% CIs were calculated by country and presented in a forest plot, along
189 with a summary statistic for the combined dataset. The following exploratory and sub-analysis were
190 undertaken to account and explore confounding factors.

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

202

203 3. Results

204 Out of the 30 included countries, the overall average prevalence of outdoor cooking in SSA was
205 42.0%, with the highest prevalence in Niger (80.0%) and lowest in Burundi (7.4%) (figure 1 and 2).
206 Regionally, western Africa had the highest prevalence (52.7%) of outdoor cooking and the lowest
207 was in East Africa (24.9%).

208 3.1. Contextual and household determinants of cooking location behaviour

209 Indoor cooking was compared to outdoor cooking in 340,334 households (table 1). A higher level of
210 educational attainment and older age of head of household were associated with increased
211 likelihood of indoor cooking, with increased odds ratio among those households with primary (AOR:
212 1.59; 95% CI: 1.54-1.65) and secondary/higher educated heads of households (AOR: 1.41; 95% CI:
213 1.35-1.47) compared to those with no education (table 2). Indoor cooking was least likely among
214 those households with younger household heads (<20 years) (AOR: 0.81; 95% CI: 0.76-0.87) and
215 most likely among those with a household head aged >60 years (AOR: 1.33; 95% CI: 1.29-1.38).
216 Increased wealth was also associated with indoor cooking, with the highest odds ratio observed in
217 those within the highest wealth quintiles compared to the lowest (AOR: 1.72; 95% CI: 1.61-1.83). Use
218 of specific fuel types was also associated with cooking location choice, with indoor cooking more
219 likely to occur among those households using agricultural biomass (straw/shrubs/grass/agricultural
220 crop/animal dung) (AOR: 1.33; 95% CI: 1.17-1.51) and less likely among coal/lignite (AOR: 0.30; 95%
221 CI: 0.27-0.35) or charcoal users (AOR: 0.59; 95% CI: 0.56-0.62) compared to wood fuel households.
222 Other household and regional level factors which were predictors of indoor cooking included
223 household with greater than six household members (AOR: 1.08; 95% CI: 1.05-1.11). However,
224 presence of a smoker in the household (AOR: 0.95; 95% CI: 0.93-0.97), higher level of female
225 empowerment (AOR: 0.85; 95% CI: 0.33-0.88) and interviews undertaken in the wet season (AOR:
226 0.73; 95% CI: 0.70-0.77) was associated with reduced odds ratio of cooking indoors.

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

233 In the stratified sub-analyses 1 by rural and urban area classification, indoor cooking was associated
234 with increasing wealth index, older household head and higher education level. However, wealth

235 index, older household head and higher greater education level had marginally higher odds ratio of
236 indoor cooking among households in rural compared to the corresponding urban area. Household
237 and contextual determinants also differed between geographic locations (appendix 4), for example
238 indoor cooking in East Africa had decreased odds ratio of primary education (AOR: 0.91; 95% CI:
239 0.85-0.95) compared to no education and in South Africa having a female (AOR: 1.61; 95% CI: 1.05-
240 1.28) and younger household heads (<20 years) (AOR: 1.61; 95% CI: 1.13-2.31) decreased increased
241 the odds of indoor cooking.

242 3.2. Child respiratory health outcomes

243 3.2.1. Respiratory symptoms

244 In the pooled data analysis we observed that in the two weeks prior to the survey 21.5% of all
245 children experienced cough, 9.6% shortness of breath and 23.5% fever (table 3), with those living in
246 outdoor cooking households being less likely to report symptoms: cough (AOR: 0.90; 95% CI: 0.86-
247 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)
248 (figure 3) than households cooking in the house; and remained associated with cooking location in
249 exploratory 2 and stratified sub-analysis 1 (table 4). However, no association was observed with
250 shortness of breath (AOR: 0.93; 95% CI: 0.85-1.01) in rural areas with stratified sub-analysis 1 (table
251 4).

252 3.2.2. Acute Respiratory Infection (ARI) and Severe Acute Respiratory Infection (SARI)

253 In the pooled dataset, the overall prevalence of ARI and SARI were 8.8% and 5.3%, respectively
254 (table 3). There were lower odds ratio of SARI (AOR: 0.87; 95% CI: 0.78-0.92) and ARI (AOR: 0.89;
255 95% CI: 0.83-0.95) among those cooking outdoors compared to in the house, and for cooking in the
256 house compared to a separate building (SARI: AOR: 0.85; 95% CI: 0.78-0.92) and (ARI: AOR: 0.89;
257 95% CI: 0.84-0.96) respectively. At a country level outdoor compared to in the house cooking was
258 associated with reduced risk of SARI in Burkina Faso, Mozambique, Togo and DRC (figure 3). With
259 ARI, a reduced risk was associated with outdoor compared to in the house cooking in Gambia,
260 Burkina Faso, Ethiopia and DRC and Cameroon (figure 3).

261 In exploratory analysis 2 investigating the effect of breastfeeding, birthweight, smoking or altitude, a
262 similar pattern was observed (table 4). In the stratified sub-analysis 1 by urban and rural status, the
263 association between cooking location and ARI (AOR: 0.90; 95% CI: 0.82-0.98) and SARI (AOR: 0.86;
264 95% CI: 0.77-0.95) remained within rural areas only (table 4). However, in urban areas only ARI was
265 associated with cooking location (AOR: 0.88; 95% CI: 0.78-0.99).

266 4. Discussion

267 In this large-scale cross-sectional study, we report the contextual, household and individual
268 determinants of outdoor household cooking location among 340,334 households (in 30 countries)
269 and identified impacts of cooking location choice upon ARI risk among 263,948 children (in 23
270 countries). We report outdoor cooking in 42% of households, with reduced odds of SARI (13%), ARI
271 (11%), cough (10%), shortness of breath (9%) and fever (15%) observed in children under five years
272 residing in outdoor biomass cooking households compared to indoor cooking households after
273 adjustment for a comprehensive range of confounding factors. Reductions in ARI through outdoor
274 cooking may reduce respiratory-related morbidity and mortality in children under five years. We also
275 identified patterns of outdoor cooking location choice which are informative for the design and
276 targeting of future HAP intervention measures, in terms of capability, opportunity and motivation
277 for behaviour change. The results showed households that are poorer, have a lower education level,

278 a younger household head and a lower level of women's empowerment were more likely to cook
279 outdoors. A decision to cook outdoors was also more likely during the dry season and at lower
280 altitudes, and is likely to reflect the importance of contextually relevant environmental
281 considerations.

282 4.1. Contextual and household determinants of cooking location choice

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

290 This study highlights a large variation in the country level prevalence of outdoor cooking behaviours
291 (figure 2), throughout SSA, in part influenced by country wealth; which was also observed at a
292 household level as an increase in wealth strongly influences cooking in a separate building, whereas,
293 as the reverse is seen in outdoor cooking compared to in the house. However, no association was
294 observed or confounding affect when attempting to account for the country level Gini index, a
295 measure of income inequality. Capability and opportunity for cooking behaviours was strongly
296 influenced by wealth, as well as, female empowerment and education, which are modifiable factors.
297 Education has previously been shown to influence the use of cleaner fuels (Rehfuess et al., 2010)
298 and should be made a priority within the design of interventions; with some current research
299 actively integrating education in to HAP interventions (Alexander et al., 2018; Hengstermann et al.,
300 2021; Nantanda et al., 2019). Although smoking is a modifiable characteristic, indoor cooking was
301 less likely among households where smoking was present. However, within a stratified analysis of
302 non-smoking households little difference in the overall effect size was observed, supporting that
303 there are differing contextual factors between cooking in the house and a separate building.

304 The type of cooking fuel used was also an important modifiable factor, as the stratified sub-analysis
305 2 of just those using wood fuel for cooking little differences were observed (table 2). Although
306 households with younger heads were more likely to cook outdoors, this could be a reflection of a
307 generational shift in cooking behaviour. Self-reporting place of cooking at time at interview, does not
308 necessarily reflect usual residence or long-term, year-round cooking habits, may explain differences
309 in outdoor cooking prevalence between the findings of this study and Langbein *et al.* (2017) findings.
310 Thus, due to the multiple confounding factors, any policy intervention to reduce HAP exposure
311 through the use of outdoor cooking should take a holistic review of the current situational and
312 target population characteristics.

313 4.2. Child respiratory health outcomes

314 The substantive variation in contextual setting, including cultural cooking practices, likely accounts
315 for the range of effect sizes for the association between cooking location respiratory health
316 outcomes by country (figure 3), despite undertaking adjustment for key confounding factors (e.g.,
317 household wealth, level of education and survey season). Furthermore, having access to electricity
318 was of borderline significance (AOR: 0.92; 95% CI: 0.85-1.00) in reducing ARI compared to not having
319 access to electricity; but access to electricity is influenced by wealth due to being included in the
320 wealth index and therefore not incorporated in the final model. Cooking in a separate building may
321 produce some respiratory-health benefit and the association remained after controlling for

322 birthweight breastfeeding, household smoking status and altitude; but caution should be maintained
323 in this interpretation as these sub-analyses were likely underpowered. In addition, the fact that no
324 associations with SARI were observed within urban areas, but are present within rural areas, is
325 suggestive of other factors within the rural-urban divide, such as co-inhabitation with livestock,
326 water, sanitation and hygiene (WASH) provision, malnutrition (Boadi and Kuitunen, 2006; Kashima et
327 al., 2010), choice of fuel (Esong et al., 2021) and levels of ambient air pollution in determining
328 childhood ARI.

329 4.3 Implications of cooking behaviour change

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

353 4.4 Strengths, limitations and further research

354 We report findings from a large sample and comparison across SSA, which reports predictors of
355 household cooking locations and indicates respiratory benefits may be associated with location
356 choice accounting for regional seasonality. However, the data was observational and not all
357 potentially relevant confounding factors could be accounted for in our analyses (e.g., ambient air
358 pollution, access to healthcare, nutritional status), which may lead to residual confounding and that
359 reverse causality cannot be ruled out. Although, some of the uncertainty around recall bias with
360 maternally reported respiratory symptoms (Odo et al., 2021); will be reduced by documenting
361 symptoms that have occurred within two weeks prior interview. Further research should focus on
362 improving the longitudinal annual characterisation of outdoor cooking patterns, with HAP exposure
363 levels and improved ARI diagnosis, to determine an exposure-response relationship. In addition, a
364 more detailed understanding is required of the potentially negative implications of outdoor cooking,
365 including safety and security, potential for insect bites, comfort for household residents and impact
366 of ambient air pollution. Further research is required to evaluate the implication and case reduction

367 of other health outcomes such as low-birthweight, women's respiratory health, malaria etc.
368 Although, outdoor cooking is a common practice within some SSA, further qualitative research into
369 the enablers and barriers of outdoor cooking, to understand the capability, opportunity and
370 motivation (Michie et al., 2011) for outdoor cooking behaviours, may increase the success of any
371 future health promotional intervention which seeks to increase outdoor cooking behaviours.

372 5. Conclusion

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

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402 Data Availability

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

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578

580 Table 1: Descriptive statistics for household and contextual determinants of cooking location at a
581 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

583 Table 2: Multilevel logistic regression for the household and contextual determinants of cooking location, showing the adjusted odds of indoor cooking (In
584 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[1.03-1.11]	<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

586 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	Yes	<i>P</i>	No	Yes	<i>P</i>	No	Yes	<i>P</i>	No	Yes	<i>P</i>	No	Yes	<i>P</i>
	(N=189,062)	(N=51,809)		(N=217,495)	(N=23,203)		(N=184,222)	(N=56,807)		(N=219,706)	(N=21,219)		(N=227,353)	(N=12,786)	
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			<0.001			<0.001			<0.001			<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
			100307						104208	
No education	91172 (48%)	18453 (36%)	(46%)	9239 (40%)	85918 (47%)	23794 (42%)	101186 (46%)	8452 (40%)	(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%)	145235	(79%)	174211 (79%)	16453	179837	10072
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
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%)	165095 (75%)	16286	170613
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%)
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%

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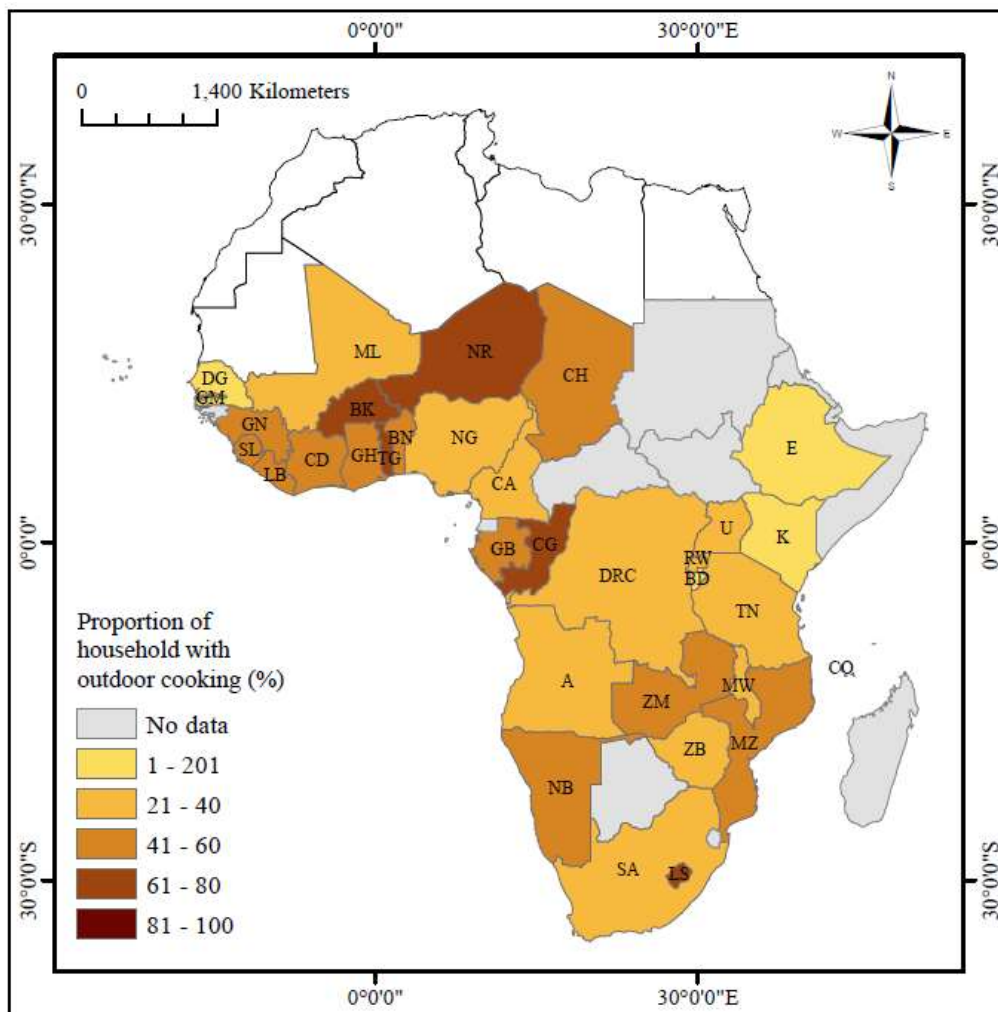
Table 4: Sensitivity analysis for breastfeeding, birthweight, altitude, urban and rural areas, presenting the adjusted odds ratio of the respiratory health outcomes with outdoor cooking compared to indoor cooking.

		Cough		Shortness of breath		Fever		ARI		SARI	
		AOR [95% CI]	<i>p</i>	AOR [95% CI]	<i>p</i>	AOR [95% CI]	<i>p</i>	AOR [95% CI]	<i>p</i>	AOR [95% CI]	<i>p</i>
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

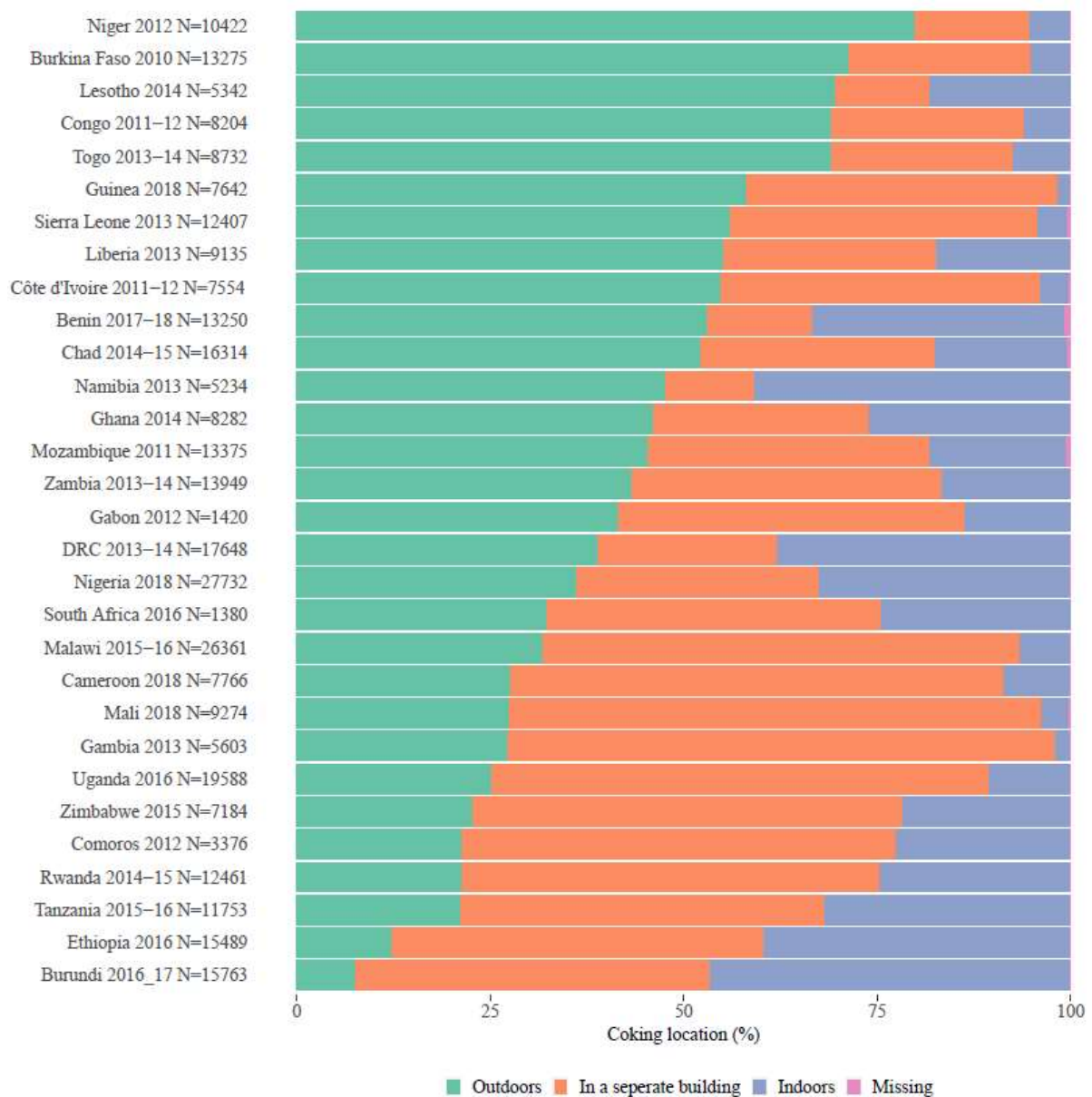
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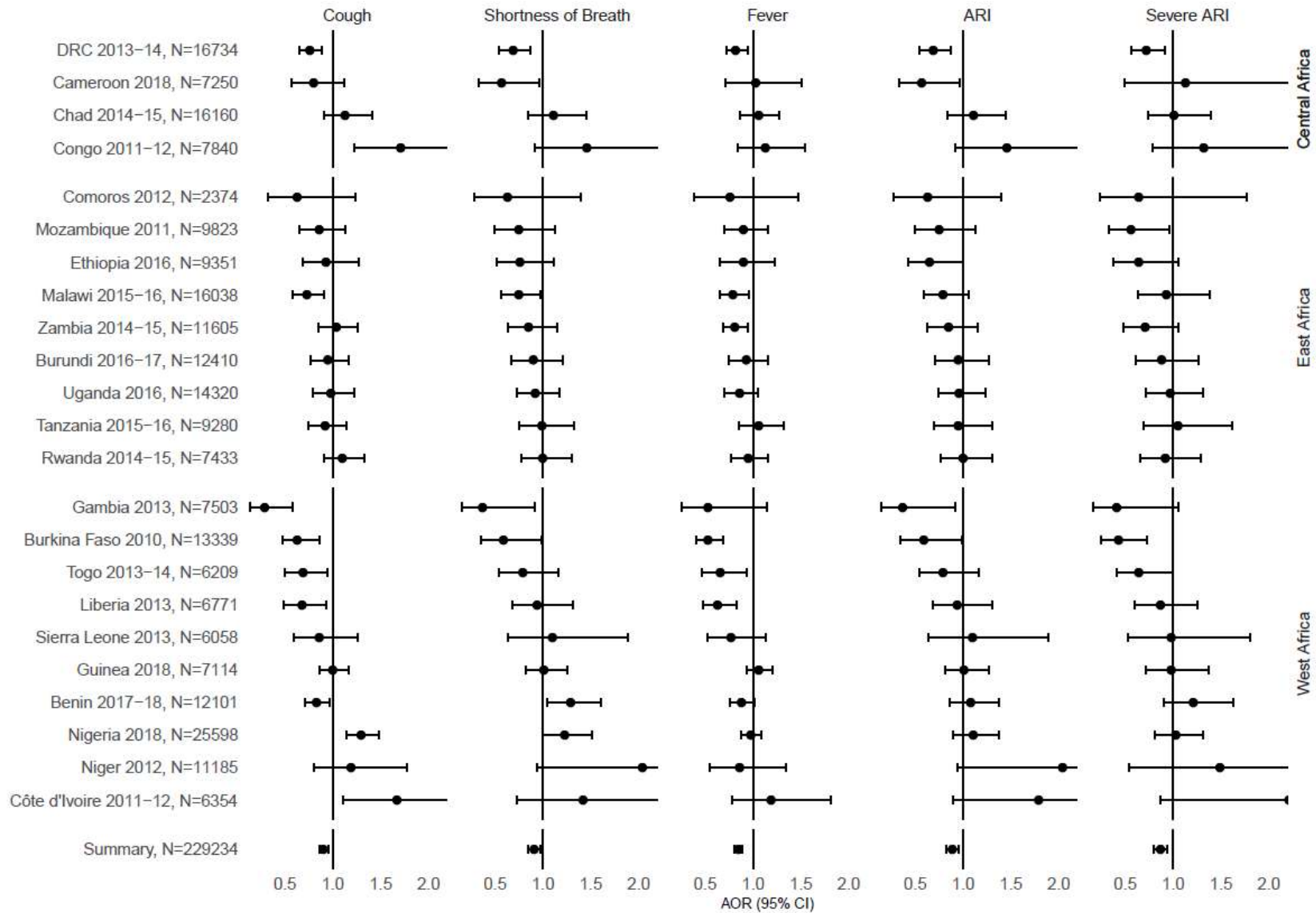
593 **Figure 1: Geographical distribution of percentage of household outdoor cooking by country.** Key: A
 594 = Angola, BN = Benin, BK = Burkina Faso, BD = Burundi, CA = Cameroon, CH = Chad, CO = Comoros,
 595 CG = Congo, DRC = Congo DRC, CD = Côte d'Ivoire, E = Ethiopia, GB = Gabon, GM = Gambia, GH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

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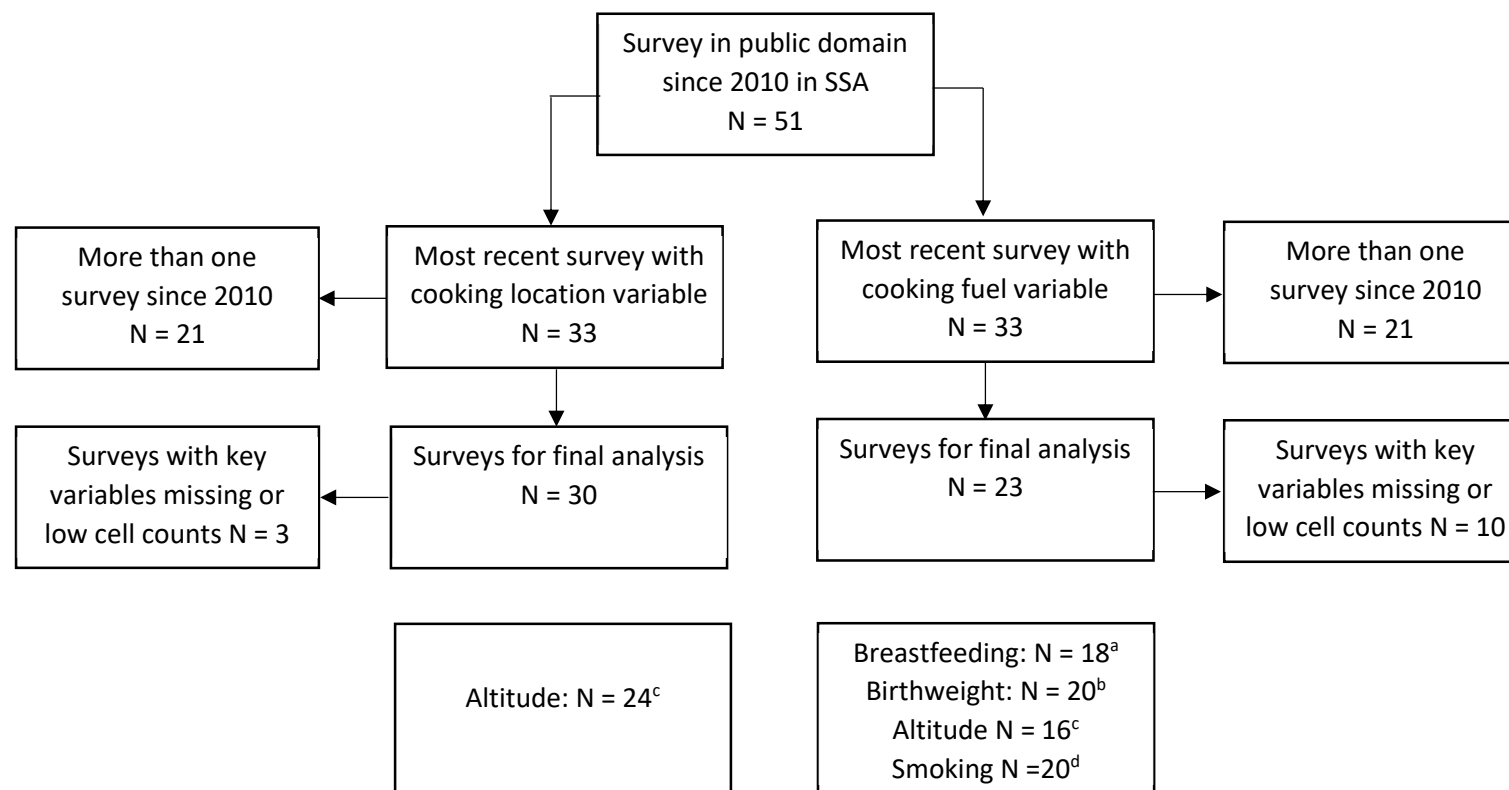
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601 **Figure 2: Proportion of households cooking outdoors, in a separate building and in the house by**
 602 **country.** Countries with survey undertaken in: wet season only = Congo, Mali, Sierra Leone; dry
 603 season only = Gabon, Gambia, Namibia,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



604

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



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

611 **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	<ul style="list-style-type: none"> • Household head education level <ul style="list-style-type: none"> • Sex of household head • Age of household head <ul style="list-style-type: none"> • Wealth index • Number of household members <ul style="list-style-type: none"> • Household smoking <ul style="list-style-type: none"> • Cooking fuel • Place of residence <ul style="list-style-type: none"> • Season • Woman empowerment <ul style="list-style-type: none"> • Altitude
Respiratory Health outcomes	Cough, shortness of breath, fever, ARI or SARI (yes, no)	Cooking location (Indoor, In a separate building, outdoor)	<ul style="list-style-type: none"> • Child's age • Child's sex • Birth order • Mode of delivery <ul style="list-style-type: none"> • Breastfeeding <ul style="list-style-type: none"> • Birthweight • Iron supplementation • Mother's education level <ul style="list-style-type: none"> • Mother's age • Woman's empowerment <ul style="list-style-type: none"> • Wealth <ul style="list-style-type: none"> • Cooking fuel • Number of household members <ul style="list-style-type: none"> • Households smoking • Regions of residence <ul style="list-style-type: none"> • Season • Altitude

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

613 Appendix 4: Sub-analysis result with adjustment of high altitude areas and by geographical region within SSA for the household and contextual
 614 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

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

Survey	Cough		Shortness of breath		Fever		ARI		SARI	
	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.