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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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- 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,
- 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
- 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
- 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
- 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
- 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,
- 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
- 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
- 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
- publicly available dataset (DHS, 2020), routinely collected and supported by the United States
 Agency for International Development (USAID). USAID provides training for government agencies
- 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
- 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
- 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
- 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
- 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
- 121 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
- 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
- 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
- All study variables are listed and described below, with appendix 3 detailing the variables whichwere 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
- 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
- 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.,

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 , \geq 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).

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

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)

- 2. Exploratory analysis 2 child respiratory health outcomes only: Undertaken among those 195 196 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) 197
- 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 household with greater than six household members (AOR: 1.08; 95% CI: 1.05-1.11). However, 223 224 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
- 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: 1.051.28) and younger household heads (<20 years) (AOR: 1.61; 95% CI: 1.13-2.31) decreased increased
- 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 children experienced cough, 9.6% shortness of breath and 23.5% fever (table 3), with those living in 245 246 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).

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).

266 4. Discussion

In this large-scale cross-sectional study, we report the contextual, household and individual 267 268 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,

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.

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

The substantive variation in contextual setting, including cultural cooking practices, likely accounts 314 315 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

- 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,
- 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
- 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 PM₁₀ (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
- 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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- 578

579 Tables

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

581 household level.

	N = 340,856 (Mi	issing = 0.15%)	
	Outdoors	Indoor	p value
	(N=134,961)	(N=198,817)	praiae
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 <u>%</u>)	

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

the house, in a separate building) compared to outdoor cooking

		a 3					Sub-analys	sis				
		ГS - D Л \	In a separate bu	uilding ^b	In the Hous	se °	Rural		Urban		Wood	
	(11 - 540,55	> 4)	(N = 276,42	24)	(N = 200,8	61	(N = 246,90	D1)	(N = 93,43	3)	(N = 254,47	74)
	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р
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 hea	ld											
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 hea	ad (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	d 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 fu	lel											
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 empowern	nent											
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 o	outdoor compared to I	ndoor (In t	he house and in a sepa	arate buildi	ing).							
b.) Cooking location is out	door cooking compared	d to in a sep	parate building.									
c.) Cooking location is outd	loor cooking compared	to in the h	nouse									

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

Cough Shortness of breath Fever ARI SARI (N =240,871, Missing = 8.7%) (N =241,029, Missing = 8.7%) (N = 240,925, Missing = 8.7%) (N = 240,139, Missing = 9.0%) (N = 240,698, Missing = 8.8%) No Yes No Yes No Yes No Yes No Yes р р р р (N=23,203) (N=189.062) (N=51.809) (N=217,495) (N=184,222) (N=56,807) (N=219,706) (N=21.219) (N=227,353) (N=12,786) < 0.001 < 0.001 < 0.001 < 0.001 < 0.001 **Cooking location** ^a In the house 35322 (19%) 11086 (22%) 41387 (19%) 5001 (22%) 33676 (18%) 12744 (23%) 41894 (19%) 4526 (21%) 43311 (19%) 2872 (23%) Separate 74105 (39%) 86814 (40%) 8584 (41%) building 21266 (41%) 85796 (40%) 9490 (41%) 73186 (40%) 22249 (39%) 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%) 0.26 0.17 0.04 0.61 0.11 Sex of child 109327 10773 114329 Male 95185 (50%) 26058 (50%) (50%) 11825 (51%) 92554 (50%) 28801 (51%) 110501 (50%) (51%) (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%) 0.01 0.01 0.3 0.009 0.78 First born 174459 147643 16817 182148 10216 (80%) (80%) (79%) (80%) No 152334 (81%) 40660 (78%) 18410 (79%) 45502 (80%) 176218 (80%) (80%) Mode of delivery ^a < 0.001 < 0.001 0.10 < 0.001 < 0.001 Caesarean 1076 (5%) 6407 (3%) 2567 (5%) 7882 (4%) 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 5104 (16%) Low 15121 (16%) 4908 (16%) 17810 (15%) 2205 (17%) 14923 (15%) 18041 (16%) 1991 (16%) 18748 (16%) 1187 (16%) Breastfeeding ^a < 0.001 < 0.001 < 0.001 < 0.001 < 0.001 5136 (3%) 5755 (3%) 494 (2%) 1243 (2%) 455 (2%) 5968 (3%) 286 (2%) Never 1120 (2%) 5021 (3%) 5805 (3%) Received Vitamin A in last 6 months ^a < 0.001 < 0.001 < 0.001 < 0.001 < 0.001 118725 12938 124406 (61%) Yes 101120 (54%) 31747 (62%) (55%) 14041 (61%) 99286 (54%) 33687 (60%) 119950 (55%) (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%) 115734 11149 120944 25-35 100944 (53%) 27107 (52%) (53%) 12225 (53%) 98595 (54%) 29576 (52%) 116931 (53%) (53%) (53%) 6707 (52%)

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

36-49	35558 (19%)	8911 (17%)		40577 (19%)	3869 (17%)		34106 (19%)	10380 (18%)		40938 (19%)	3536 (17%)		42138 (19%)	2178 (17%)	
Mother's educa	ation 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 Secondary or	63538 (34%)	21181 (41%)		75266 (35%)	9397 (41%)		62789 (34%)	21985 (39%)		76240 (35%)	8511 (40%)		79116 (35%)	5212 (41%)	
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%)	
				172388			145235				16453		179837	10072	
Wood Other	151536 (80%)	39089 (75%)		(79%)	18082 (78%)		(79%)	45459 (80%)		174211 (79%)	(78%)		(79%)	(79%)	
biomass	4450 (2%)	1372 (3%)		5234 (2%)	587 (3%)		4472 (2%)	1359 (2%)		5291 (2%)	531 (3%)		5443 (2%)	364 (3%)	
Number of hou	sehold membe	rs ^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 smo	oking ^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 Reside	nce		<0.001			< 0.001			< 0.001			<0.001			< 0.001
				163228			137340				16286		170613	10008	
Rural	143150 (76%)	38186 (74%)		(75%)	17987 (78%)		(75%)	44111 (78%)		165095 (75%)	(77%)		(75%)	(78%)	
Season			0.21			<0.001			<0.001			<0.001	10000		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	22220 (4470)	22200 (4370)	0.001	55262 (4470)	5270 (4070)	0.27	33200 (4470)	20400 (40/0)	<0.001	50000 (4470)	0,00(41/0)	0.17	(1170)	5.00 (4070)	0.19
High	1761 (1%)	454 (1%)		<u>1944</u> (1%)	271 (2%)		1873 (1%)	343 <u>(</u> 1%)		1964 (1%)	<u>251 (</u> 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%

588 Table 4: Sensitivity analysis for breastfeeding, birthweight, altitude, urban and rural areas, presenting the adjusted odds ratio of the respiratory health outcomes with

589 outdoor cooking compared to indoor cooking.

		Cough		Shortness of b	reath	Fever		ARI		SARI	
		AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р
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	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
(11-209,585)	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	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
(11-183,924)	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	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
(n=178,334)	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	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
(11-231,608)	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 $(n=02,608)$	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

591 Figures



592

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

Leone, SA = South Africa, TN = Tanzania, TG = Togo, U = Uganda, ZM = Zambia and ZB = Zimbabwe.



Niger 2012 N=10422 Burkina Faso 2010 N=13275 Lesotho 2014 N=5342 Congo 2011-12 N=8204 Togo 2013-14 N=8732 Guinea 2018 N=7642 Sierra Leone 2013 N=12407 Liberia 2013 N=9135 Côte d'Ivoire 2011-12 N=7554 Benin 2017-18 N=13250 Chad 2014-15 N=16314 Namibia 2013 N=5234 Ghana 2014 N=8282 Mozambique 2011 N=13375 Zambia 2013-14 N=13949 Gabon 2012 N=1420 DRC 2013-14 N=17648 Nigeria 2018 N=27732 South Africa 2016 N=1380 Malawi 2015-16 N=26361 Cameroon 2018 N=7766 Mali 2018 N=9274 Gambia 2013 N=5603 Uganda 2016 N=19588 Zimbabwe 2015 N=7184 Comoros 2012 N=3376 Rwanda 2014-15 N=12461 Tanzania 2015-16 N=11753 Ethiopia 2016 N=15489 Burundi 2016_17 N=15763

600

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.



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.

607 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

			House	constr	ruction		T			1				Asset	S							r						ы
Country	source of drinking water	Foilet facility	Wall material	Soof material	-loor material	electricity	Sadio	Television	Refrigerator	vatch	licycle	Motorcycle or scooter	Animal-drawn cart	Car or Truck	3oat with a motor	3ank account	Mobile telephone	Computer	Von-motorised boat or canoe	[ractor	Jough	Household furniture*	Household electronics*	Other assets*	Dwelling window material	Lighting fuel	Refuse collection	Own or rent house/type of dwellir
Benin 2017-18																										1		
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																												

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

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)

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	 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.

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		East		South		West		Central	
	(N = 272,63	38)	(N = 13,60	18)	(N = 13,07	4)	(N = 13,57	94)	(N = 55,44	8)
	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	р	AOR [95% CI]	p	AOR [95% CI]	р
Head of household's edu	cation 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 (y	vears)									
<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 me	embers									
>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.									
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).

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