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The impact and level of household air pollution (based on combustion process) in stunting among children under five years old: A Secondary analysis of DHS data in West Africa

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Abstract:
Among underlying causes associated to stunting, is unhealthy domestic environment includedindoor air pollution justifying this study. This is a retrospective cross-sectional study, in which we did a secondary analysis on datafrom West African Economic and Monetary Union member states' Demographic and Health Surveyto assess relationship between indoor air pollution and stunting among children under five. Questions relating to indoor air degradation factors have been used to create a composite indicator of pollution("Household level of air pollution"). Occurrence of stunting varies but remains high: 33.0% (Burkina Faso), 31.4% (Benin), 29.0% (Ivory Coast) 26.3% (Togo) 16.5% (Senegal). Prevalence is distributed mainly between households with a medium level of pollution and those with a high level, part of the latter varies between 7.6% (Senegal) to 77.4% (Burkina Faso). Logistic regression reveals excess risk (AOR [95% CI]) associated to high level of pollution in Benin (1.75 [1.39 - 2.20], Burkina Faso (3.21 [1.16 - 8.83]), Senegal (1.42 [1.05 - 1.92]), and in Togo (2.00 [1.11 - 3.62].Indoor air pollution is a risk factor associated to stunting and must be taken into account in the causal analysis model of malnutrition.

Keywords:*Indoor air pollution; Domestic combustion processes; African Economic and Monetary Union area; Stunting; Children under-five; Demographic and Health Survey*

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I. INTRODUCTION

Malnutrition weighs 35% to 55% of the disease burden in children under five(Black et al. 2008; Pelletier, Frongillo, and Habicht 1993). The latter are confronted with different forms of malnutrition (stunting or even chronic malnutrition, underweight and acute malnutrition)(UNICEF 2013, 2016) which expose them to infectious diseases(Ndamobissi 2017) and to a greater susceptibility to chronic diseases in adulthood(Storme et al. 2014). Indeed, 150.8 millions of them are stunted, 50.5 million are wasted and 20 million babies are born with low birth weight each year(Fanzo et al. 2019; UNICEF and WHO 2019). It partly explains the WHO's 2025 goals: to reduce stunting by 40% in children under five; toreduce low birth weight by 30%; to reduce and maintain child wasting below 5%. Regarding stunting, it has certainly decreased globally in recent years, but the prevalence remains high, especially in Africa. Between 2000 and 2017, prevalence fell from 32.6% to 22.2% globally, from 38.1% to 23.2% in Asia, from 6.9% to 9.6% in Latin America and in the Cariban and from 38.3% to 30.3% in Africa(Fanzo et al. 2019). This makes it necessary to research explanatory factors for occurrence of stunting in children in order to control them and make further progress towards achieving the goals defined above. Since 1990, a model has been adopted as a standard conceptual framework for the causal analysis of malnutrition by the United Nations Children's Fund(UNICEF 1998). This model identifies as the underlying causes of malnutrition, a group of three determinants manifested mainly within the household. These include, in particular, food insecurity, behaviors focused on seeking care and finally, inadequacy of health services and water supply and the unhealthy domestic environment(Ndamobissi 2017; UNICEF 1998). Regarding the water supply, it is considered adequate when the household uses an improved water source, located on site, available on demand and meeting standards for faeces and chemicals of priority interest.Environmental health, on the other hand, is mainly associated with the use of improved sanitation facilities at home, not shared with other householdsof whose excreta are treated and disposed *in situ*, or transported and disposed off-site,it is also associated with good hygiene practices such as hand washing(WWAP 2017). In addition to hygiene and sanitation services, environmental health could be assessed through indoor air pollution, although its implication in malnutrition appears to be limited to birth weight(Delpierre et al. 2016; Ouidir 2017; Rousseau 2016). This pollution can come from various sources, it can be natural as well as anthropic and corresponds to a heterogeneous mixture of chemical compounds in gaseous form (NO_x, CO, O_3, Benzene, etc.) or particulate (PM_{10}, $PM_{2.5}$, etc.) adsorbed by organic and inorganic substances(Delpierre et al. 2016; Ouidir 2017). In Africa, anthropic sources are concentrated near or even inside dwellings. In fact, a large part of households uses rudimentary means (solid fuels, open stoves on living rooms) in cooking activities, causing high emissions of pollutants into indoor air(IEA 2021; Kafando et al. 2019; Ndong 2019; Sana 2020; Smith, Rogers, and Cowlin 2005). Several other households still depend on polluting fuels to meet their lighting needs, and are also exposed to other factors that affect indoor air quality, such as smoking and the incineration of waste(Barron and Torero 2017; Ndong 2019). To these factors can be added the very frequent use of incense, demographic pressure and the influence of urban traffic(Ndong 2019). Moreover, in Africa and more particularly in West African Economic and Monetary Union space (WAEMU), few studies have looked at indoor air pollution and its health impact, even less on the nutritional status of children(Fayiga, Ipinmoroti, and Chirenje 2018; Kafando et al. 2019; Kouao et al. 2019; Ndong 2019; Sana et al. 2020). It therefore appears justified to find alternatives aimed at filling this gap, hence the present work which aims to help document the link between indoor air pollution and stunting, a form of malnutrition that mainly affects children under five

II. Material and Methods

Setting and study design

We conducted a retrospective cross-sectional study, in which we did a secondary analysis on a dataset from West African Economic and Monetary Union (WAEMU) member states' Demographic and Health Survey (DHS). Except Guinea Bissau which is not concerned by the DHS program and therefore is excluded from this study, these surveys were conducted nationwide in each country. WAEMU brings together eight Sahelian countries, linked by a common currency and cultural traditions: These are Benin, Burkina Faso, Mali, Niger, Ivory Coast, Guinea-Bissau, Senegal and Togo located in West Africa(UEMOA 2021a, 2021b).It covers an area of 3.5 million km^2 and has more than 120 million inhabitants of which 34.8% established in urban areas with disparities between countries(IDATE DigiWorld 2020; AFRISTAT 2019). Indeed, the urban population is larger in Ivory Coast (53.8%), Senegal (46.5%) and Benin (44.6%) and lower in Niger (14.9%). In addition, the Ivory Coast represents 20.6% of the total population of the area followed by Niger with 17.3%(AFRISTAT 2019). The area faces challenges related to poverty, difficult access to basic social services, high fertility and is characterized by high infant mortality(AFRISTAT 2019).

Sampling and datacollection

DHS surveys are designed to be nationally representativeand are intended to provide information on population, family planning, maternal and child health, child survival status, HIV / AIDS and Sexually Transmitted Infections (STIs), reproductive health and nutritional status. In each county, data collection is done through a stratified multi-stage cluster sample design. At the first stage, Enumeration Areas (EA) were identified and then drawn from the list established during the last General Population and Housing Census. The second stage consisted of drawing a sample of households in each selected EA.Participants in the survey include women aged 15-49 years old, men aged 15-59 years old and children under five years old. Mothers were asked to respond the survey questions on behalf of their children, on their health status and demographic characteristics. Four questionnaires are used to collect data: the household questionnaire, the female questionnaire, the male questionnaire and the biomarker questionnaire. The household questionnaire is used to collect information on household characteristics (main source of drinking water, type of toilet, hand washing equipment, source of lighting, fuel and place of cooking, passive smoking, etc.). This work also identified household members with regard to their socio-demographic characteristics (age, sex, level of education, etc.) according to women, men and children eligible for individual interviews and / or for biological tests and measurements are identified. The individual male and female questionnaires are respectively intended to collect information concerning them, while the biomarker questionnaire is used to collect anthropometric data (weight and height) and collect information on anaemia, malaria and blood samples taken for the test. of HIV(INS and ICF International 2013; INS and ICF International 2012; ANSD and ICF 2018; INSTAT, CPS/SS-DS-PF, and ICF International 2019; INSAE and ICF International 2019; INSDand ICF International 2012; MPDAT, ICF International, MS 2015). Results presented in this paper are from information about households and children under five years old included in sixth DHS (Burkina Faso, Ivory Coast) and seventh DHS (Benin, Senegal, Togo, Mali).The databases were obtained following a request and justification for the study from the DHS program. Niger was excluded from the study due to the unavailability of certain variables of interest in the database.

Operational description of variables

Dependant variable: Stunting:In children, malnutrition derives from poor growth, as malnourished children are smaller and lighter than their age(UNICEF 1998). There are several clinical forms of malnutrition, and stunting or chronic malnutrition is defined as dependent variable in thisstudy. Nutritional anthropometry is one method of assessing this stunting. The height-for-age indicator used for this purpose is based on body measurements of height and age and is expressed as a number of standard deviation units (also called Z-score) compared to the median of the WHO Child Growth Standard (WHO, 2006): *Z-Score (height-for-age) =* $(Te - Tm)/ET$; with *Te* = Height of the child, *Tm* = Median height in the reference population, *ET* = Standard deviation in the reference population. Children below two standard deviations (Z-score $\leq$ (-2)) are considered to be stunted(Cogill 2003).

Main exposure factor: "Household level of air pollution":In accordance with the objective to assess the link between indoor air pollution and stunting, a composite variable called Household level of air pollution, indicator of indoor pollution was created based on questions relating to the factors of degradation of indoor air quality. These questions are shown in Table 1 along with the possible answers proposed by DHS. We first grouped the responses before assigning them a score. Regarding the type of cooking fuel, the grouping is based on the work of Mishraand al.(Mishra 2003). The maximum score that a household can achieve is 10. We subsequently defined three score levels for the Household level of air pollution variable corresponding to low level of pollution for households with a score less than 4, medium level of pollution for those with a score in the range [4 - 6] and high level of pollution when the score is greater than 6.

Table 1: Construction of Household level of air pollution variable

Questions	Possible answers/codes	Recoded as	Scoring
does your household have electricity?	yes		0
	no		1
what type of fuel does your household mainly use for cooking?	electricity, lpg, natural gas, biogas	low pollution fuels	1
	Kerosene, coal/lignite, charcoal	medium pollution fuels	2
	wood, straw/shrubs/grass, agricultural crop, animal dung	high pollution fuels	3
is the cooking usually done in the house, in a separate building, or outdoors?	outdoors		1
	in a separate building		2
	in the house		3
how often does anyone smoke inside your house? would you say daily, weekly, monthly, less often than once a month, or never?	never	never	0
	Weekly Monthly less often than once a month	sometimes	1
	daily	daily	2
do you currently smoke cigarettes every day, some days, or not at all?	every day some days	yes	1
	not at all	no	0

Stunting is the result of several underlying causes, the age of mother and that of child, as well as sex of the child in addition to other variables relating to environmental health (access to water, hygiene and sanitation) were identified as adjustment factors for the present study. Access to water is measured by variables "*main source of drinking water*" and "*location of the main source of drinking water*" while sanitation is measured by variables "*type of toilet usually used"* and "*sharing toilets with other households*". As for hygiene practices, they correspond to following group of variables: "*availability of hand washing equipment*", "*availability of water at the hand washing place*" and "*availability of soap or detergent at the place of washing*".Proposed answers according to the DHS for the above-mentioned variables have been recorded in order to simplify their interpretation and the comparison of results to other research work. Concerning variables "*main source of drinking water*" and "*type of toilet usually used*", responses were grouped into two modalities "*improved*" and "*unimproved*" according to guidelines of Joint Program WHO/UNICEF for Monitoring water supply and sanitation (JMP)(Croft, Allen, and Marshall 2018)(Table 2).

Table 2: Recoding of response options for adjustment variables

Questions	Possible answers/codes	Recodedas
The main source of drinking water for members of the household	piped into dwelling; piped to yard/plot; public tap/standpipe; piped to neighbour; tube well or borehole; protected well; protected spring; rainwater; tanker truck; cart with small tank; bottled water;	Improved
	unprotected well; unprotected spring; river/dam/lake/ponds/stream/canal/irrigation channel; other	Unimproved
Type of toilet facility in the household	flush to piped sewer system; flush to septic tank; flush to pit latrine; flush, don't know where; ventilated improved; pit latrine; pit latrine with slab; composting toilet;	Improved
	flush to somewhere else; pit latrine without slab/open pit; hanging toilet/latrine; bucket toilet; other	Unimproved

Statistical analysis

We first determined the prevalence of stunting in each country as well as its distribution according to different characteristics including the main exposure factor and the identified adjustment factors. The second phase of analysis was carried out by measurements of association using the chi-square's test and logistic regression with a significance threshold set at 5%. In addition to the main exposure factor, the univariate regression concerned the variables significantly associated with the occurrence of stunting with regard to the chi-square's test p-value. The main exposure factor as well as the variables with a p-value less than 20% were subsequently included in a Backward Stepwise Regression procedure to fit a multivariable model. The odds ratios (Crude Odds Ratios (COR) and Adjusted Odds Ratios (AOR)) were estimated along with their 95% confidence intervals (95% CI). All the statistical analyses were carried out using the R software, the "survey" package made it possible to weight all the observations in order to compensate for the oversampling of certain categories of respondents and to take into account the complexity of the sampling plan.

Ethics

DHS surveys and methodology were reviewed and approved by the International Coach Federation (ICF) (see more at http://dhsprogram.com/). Also, the survey was approved by Senegal Institutional Review Board (IRB) before data collection, and all participants provided informed consent to the surveyors.

III. RESULTS

Factors includedin «Household level of air pollution » variable

Results reveal a predominance of households mainly using highly polluting fuels for cooking activities (Benin: 65.9%; Burkina Faso: 87.7%; Ivory Coast: 60.2%; Mali: 77.9%; Togo: 49.4%). Wood and charcoal (biomass fuel) are respectively used for: 61.9% and 26.7% (Benin); 87.5% and 4.3% (Burkina Faso); 60.1% and 17.6% (Ivory Coast); 77.6% and 19.3% (Mali); 0.0% and 18.9% (Senegal); 1.4% and 48.2% (Togo). Cooking is mainly done outdoorof habitat (Benin: 50.6%; Burkina Faso: 67.9%; Côte d'Ivoire: 50.6%; Togo: 66.6%) except in Mali, where it mainly takes place inside in a separate room (68.8%) and in Senegal, where it is mostly done in housing (71.3%). In terms of access to electricity, the highest rates are noted in Senegal (63.3%) and Ivory Coast (55.9%) while in the other countries, more than half of households did not haveaccess (Benin: 64.4%; Burkina Faso: 86.8%; Mali: 51.4%; Togo: 54.2%). Daily exposure to environmental tobacco is higher in Burkina Faso (21.3%) and Côte d'Ivoire (21.8%) than in the other countries (Benin: 8.5%; Mali: 16.2%; Senegal: 19.3%; Togo: 13.5 %) and cigarette smoking by mothers whose children were included in study remains low and varies between 0.0% (Togo) and 1.6% (Benin).

Prevalence measurement and chi-square test

Table 3 summarizes results of prevalence measurement and the chi-square test. Occurrence of stunting varies from one country to another but remains high in the WAEMU area: 33.0% (Burkina Faso), 31.4% (Benin), 29.0% (Ivory Coast), 26.3% (Togo) and 16.5% (Senegal). Prevalence is distributed mainly between households with amedium level of pollution and those with a high level and the part of the latter varies between 7.6% (Senegal) to 77.4% (Burkina Faso). Regarding the chi-square test, except for Mali (p-value = 0.061), the results were significant with p-values <0.0001 for the main exposure factor. Child's age, "*main source of drinking water*", "*type of toilet usually used*", "*availability of soap or detergent at handwashing place*" were also associated with occurrence of stunting in all countries. With the exception of Togo (p-value = 0.352), the sex of the child is also a factor associated with occurrence of stunting, while "*sharing toilets with other households*" and mother's age were only associated with it, respectively, in Benin (p-value <0.001) and Senegal (p-value = 0.019).

Table 3: Bivariate association between stunting and selected characteristics of children and households in WAEMU countries

Variables	Benin	Burkina Faso	Ivory Coast	Mali	Senegal	Togo
Stunted child[1]						
n	11540	6775	3229	8357	10447	3162
yes	31.4	33.0	29.0	26.0	16.5	26.3
no	68.6	67.0	71.0	73.5	83.5	73.7
Repartition of stunting prevalence						
Household level of air pollution						
low level of pollution	6.0	0.2	3.3	0.5	22.1	2.3
medium level of pollution	43.5	22.4	49.5	71.3	70.3	42.2
high level of pollution	50.5	77.4	47.2	28.3	7.6	55.5
p-value	**< 0.0001**	**< 0.0001**	**< 0.0001**	0.061	**< 0.0001**	**< 0.0001**
Source of drinking water						
unimproved	63.6	27.0	29.6	40.5	30.7	46.5
improved	63.7	73.0	70.4	59.5	69.3	53.5
p-value	**< 0.0001**	**0.004**	**0.002**	**< 0.0001**	**< 0.0001**	**< 0.0001**
Location of source for water						
in own dwelling/yard/plot	13.0	3.0	16.1	16.1	12.3	6.4
elsewhere	87.0	97.0	83.9	83.9	87.7	93.6
p-value	**< 0.001**	**0.018**	0.078	0.499	0.300	**0.026**
Type of toilet facility						
unimproved	12.3	6.2	14.9	41.9	27.7	9.7
improved	21.4	16.8	30.6	47.8	50.0	19.7
bush/field	66.3	77.0	54.6	10.3	22.3	70.6
p-value	**< 0.0001**	**< 0.0001**	**< 0.0001**	**<0.0001**	**< 0.0001**	**< 0.0001**
Share toilet with other households						
yes	70.7	50.2	67.8	41.3	26.3	34.4
no	29.3	49.8	32.2	58.7	73.7	65.6
p-value	**< 0.001**	0.859	0.579	0.070	0.095	0.993
Hand washing place inside the house						
observed place	56.1	72.9	42.0	68.9	32.2	11.4
not observed place	43.9	27.1	58.0	31.1	67.8	88.6
p-value	0.475	0.262	**0.012**	0.962	**< 0.0001**	**0.012**
Presence of water at hand washing place						
yes	35.0	46.4	38.6	43.6	51.5	59.3
no	65.0	43.6	61.4	56.4	48.5	40.7
p-value	**< 0.0001**	0.544	0.570	0.712	**0.002**	**< 0.001**
Soap or detergent available at hand washing place						
yes	12.4	10.7	17.9	16.6	37.5	47.4
no	87.6	89.3	82.1	83.4	62.5	52.6
p-value	**< 0.0001**	**0.003**	**0.003**	**< 0.0001**	**< 0.0001**	0.066
Mother's age in years						
<18	1.0	0.7	2.9	2.5	1.1	0.8
18 - 24	24.8	27.7	29.9	24.9	24.0	20.8
25 - 34	52.2	48.2	46.2	49.0	47.1	50.5
>34	22.0	23.4	21.0	23.7	27.8	28.0
p-value	0.393	0.735	0.422	0.134	**0.019**	0.871
Children's current age						
< 1	14.5	8.9	12.0	11.6	11.7	10.9
1 - 2	22.0	20.9	24.4	24.8	25.0	19.9
2 – 3	24.0	28.2	28.4	25.0	28.2	24.7
> 3	39.5	42.0	35.2	38.6	35.1	44.5
p-value	**< 0.0001**	**< 0.0001**	**<0.0001**	**<0.0001**	**< 0.0001**	**<0.0001**
Children's Sex						
male	55.0	54.5	47.9	53.1	56.4	51.6
female	45.0	45.5	52.1	46.9	43.6	48.4
p-value	**< 0.0001**	**< 0.001**	**0.009**	**0.049**	**< 0.0001**	0.352

Impact measurement by logistic regression

In simple regression, results reveal an excess risk associated with exposure to a high level of pollution regard to COR and 95% CI: 2.44 [1.98 - 3.00] (Benin), 9.03 [3.48 - 23.47] (Burkina Faso), 3.06 [1.78 - 5.31] (Ivory Coast), 2.39 [1.19 - 4.77] (Mali), 2.40 [1.82 - 3.17] (Senegal), 2.14 [1.25 - 3.65] (Togo). Tables 4 and 5 summarize results of multivariable regression used to adjust the previously estimated risks. Estimates (AOR [95% CI]) also reveal excess risk in Benin (1.75 [1.39 - 2.20], Burkina Faso (3.21 [1.16 - 8.83]), Senegal (1.42 [1.05 - 1.92]), and in Togo (2.00 [1.11 - 3.62].

Table4: Multivariable logistic regression between stunting and household level of air pollutions, adjusted for some others variables

	Benin			Burkina Faso			Ivory Coast		
	AOR	95% CI	p	AOR	95% CI	p	AOR	95% CI	p
Household level of air pollution									
low level of pollution[ref]									
medium level of pollution	1.37	[1.12 - 1.68]	0.003	3.06	[1.11 - 8.37]	0.030	1.28	[0.69 - 2.40]	0.429
high level of pollution	1.75	[1.39 - 2.20]	<0.0001	3.21	[1.16 - 8.83]	0.025	1.54	[0.82- 2.93]	0.181
Children's current age									
> 3[ref]									
<1	0.43	[0.38 - 0.49]	<0.0001	0.27	[0.22 - 0.32]	<0.0001	0.39	[0.28 - 0.55]	<0.0001
1 - 2	0.94	[0.84 - 1.06]	0.345	0.93	[0.80 - 1.08]	0.36	1.07	[0.82 - 1.32]	0.639
2 – 3	1.35	[1.20 - 1.52]	<0.0001	1.57	[1.35 - 1.83]	<0.0001	1.63	[1.26 - 2.10]	<0.001
Children's sex									
male[ref]									
female	0.77	[0.71 - 0.84]	<0.0001	0.79	[0.70 - 0.89]	<0.001	0.72	[0.58 - 0.88]	0.002
Source of drinking water									
improved[ref]					-			-	
unimproved	1.15	[1.01 - 1.29]	0.026						
Location of water source									
in own dwelling/yard/plot[ref]									
elsewhere	1.22	[1.03 - 1.44]	0.020	1.35	[0.97 - 1.89]	0.075			
Type of toilet facility									
improved[ref]									
unimproved	1.24	[1.03 - 1.48]	0.018	1.34	[0.99 - 1.83]	0.058	1.25	[0.90 - 1.73]	0.185
bush/field	1.66	[1.38 - 2.00]	<0.0001	1.71	[1.43 - 2.03]	<0.0001	2.26	[1.76 - 2.90]	<0.0001
Share toilet with other households									
no[ref]					-			-	
yes	1.27	[1.07 – 1.52]	0.008						
Presence of water at hand washing place									
water is available[ref]					-			-	
water is not available	1.14	[0.97 - 1.34]	0.120						
Soap or detergent available at hand washing place									
yes[ref]									
no	1.27	[1.02 - 159]	0.035		[1.11 - 1.74]	0.003	1.43	[1.00 - 2.05]	0.051

Table5: Multivariate logistic regression between stunting and household level of air pollution (based on combustion process), adjusted for some others variables (continued)

	Mali			Senegal			Togo		
	AOR	95% CI	p	AOR	95% CI	p	AOR	95% CI	p
Household level of air pollution									
low level of pollution[ref]									
medium level of pollution	1.78	[0.86 - 3.67]	0.120	1.35	[1.12 - 1.64]	0.002	1.45	[0.81 - 2.58]	0.204
high level of pollution	1.88	[0.91 - 3.84]	0.085	1.42	[1.05 - 1.92]	0.021	2.00	[1.11 - 3.62]	0.021
Children's current age									
> 3[ref]									
<1	0.43	[0.36 - 0.51]	<0.0001	0.55	[0.46 - 0.69]	<0.0001	0.32	[0.24 - 0.43]	<0.0001
1 - 2	1.16	[0.99 – 1.34]	0.060	1.32	[1.14 - 1.54]	<0.001	0.66	[0.52 - 0.84]	<0.001
2 – 3	1.53	[1.30 - 1.80]	<0.0001	1.84	[1.58 - 2.13]	<0.0001	1.11	[0.89 - 1.38]	0.362
Children's sex									
male[ref]									
female	0.85	[0.76 - 0.96]	0.008	0.79	[0.70 - 0.89]	<0.001	0.89	[0.73 - 1.07]	0.200
Source of drinking water									
improved[ref]									
unimproved	1.52	[1.32 - 1.74]	<0.0001	1.52	[1.31 - 1.76]	<0.0001		[1.31 - 1.89]	<0.0001
Location of water source									
in own dwelling/yard/plot[ref]		-			-				
elsewhere								[1.05 - 2.23]	0.027
Type of toilet facilities									
improved[ref]									
unimproved	1.26	[1.08 - 1.47]	0.003	1.59	[1.34 - 1.87]	<0.0001	1.66	[1.07 – 2.55]	0.023
bush/field	1.05	[0.86 - 1.30]	0.589	1.67	[1.38 - 2.02]	<0.0001	2.12	[1.61 - 2.80]	<0.0001
Hand washing place									
observed place[ref]		-			-				
not observed place								[1.08 - 1.83]	0.012
Presence of water at hand washing place									
water is available[ref]		-			-				
Water is not available							1.94	[1.15 - 3.28]	0.014
Soap or detergent available at hand washing place									
yes[ref]								-	
no	1.39	[1.16 - 1.67]	<0.001	1.45	[1.11 - 1.90]	0.007			
Mother's age in years									
25 – 34[ref]									
<18		-		1.33	[0.79 - 0.22]	0.279		-	
18 - 24				1.18	[1.02 - 1.37]	0.025			
>34				1.06	[0.91 - 1.23]	0.446			

IV. DISCUSSION

Malnutrition is a public health problem everywhere else. Indeed, among the many problems facing the international community, malnutrition figures prominently, hence the WHO 2025 goals: to reduce stunting by 40% in children under five; to reduce low birth weight by 30%; to reduce and maintain child wasting below 5%. Progress towards these targets is being noted around the world, however, it remains insufficient for their achievement by the desired timeframe. Regarding stunting, prevalence remains high in children under five, especially in Africa, making it necessary to research explanatory factors for its occurrence, hence this study, initiated with the aim of documenting its link with indoor air pollution.

This is a retrospective cross-sectional study, in which we did a secondary analysis on a dataset from West African Economic and Monetary Union (WAEMU) member states' Demographic and Health Survey (DHS). This does not include an air quality metrology, however, questions ("*Does your household have electricity?*"; "*What type of fuel does your household mainly use for cooking*?"; "*Is the cooking usually done in the house, in a separate building, or outdoors?*"; "*How often does anyone smoke inside your house*?"; "*Would you say daily, weekly, monthly, less often than once a month, or never*?"; "*Do you currently smoke cigarettes every day, some days, or not at all*?"), relating to the degradation factors of indoor air quality have been used to create a composite indicator called "*Household level of air pollution*".Indeed, use of biomass (mainly wood and charcoal) as cooking energy causes high indoor air pollution due to the composition (NOx, CO, O_3, Benzene, PM_{10}, $PM_{2.5}$, etc.) of the smoke they emit(Larson and Koenig 1994; Smith, Rogers, and Cowlin 2005). Cooking place also determines indoor air quality. Due to poor ventilation, households without a separate kitchen from their accommodation are exposed to higher levels of pollution(Raj 2020). In addition, it is not the only fact of cooking activities, environmental tobacco and absence of electricity can contribute to the degradation of indoor air (Barron and Torero 2017; Blimpo and Cosgrove-Davies 2020). Indeed, in the absence of electricity, households mainly resort to polluting fuels such as kerosene, to ensure their lighting needs(Barron and Torero 2017). As for tobacco, and particularly cigarettes, when used in an oxygen-depleted space, its smoke may be comparable to that of biomass(Blimpo and Cosgrove-Davies 2020; OMS and UEMOA 2015).

Among eight WAEMU countries, two were excluded: This is Guinea Bissau, not concerned byDHS program and Niger for which certain variables on combustion processes were not available in the database. In total, study included 43,510 children (Benin: 11540; Burkina Faso: 6775; Côte d'Ivoire: 3229; Mali: 8357; Senegal: 10447; Togo: 3162) for 65705 households (Benin: 14156; Burkina Faso: 14424; Côte d'Ivoire: 9686; Mali: 9510; Senegal: 8380; Togo = 9549).

Occurrence of stunting varies from one country to another but remains high in the WAEMU region: 33.0% (Burkina Faso), 31.4% (Benin), 29.0% (Ivory Coast) 26.3% (Togo) 16.5% (Senegal). Prevalence noted are well above for Latin America and Caribbean (6.9% to 9.6%) but do not deviate too much from those for Africa (38.3% to 30.3 %), except for Senegal [(Fanzo et al. 2019)].Prevalence is distributed mainly between households with a medium level of pollution and those with a high level and the part of the latter varies between 7.6% (Senegal) to 77.4% (Burkina Faso).

Regarding the chi-square test, except for Mali (p-value = 0.061), results were significant with p-values <0.0001 for the main exposure factor. Several studies have indeed noted a higher prevalence of stunting among children from households exposed to factors that affect indoor air quality. Use of highly polluting fuels thus multiplies prevalence by two compared to fuels with low pollution levels (43.47% against 25.82%) and this prevalence is higher among children from households which cook indoor housing (41.05%) compared to those that cook outdoor (36.57%)(Dadras and Chapman 2017). A similar result was observed in another study, prevalence of stunting among children living in households with separate kitchens from the accommodation (19% to 21%) was slightly lower than that observed in households without separate kitchens (24% to 28%)(Mishra and Retherford 2007). In addition, children exposed to tobacco smoke are more sensitive to stunting, both when the mother smokes herself (61.44%)(Dadras and Chapman 2017) than when it is an environmental tobacco exposure (51%)(Mishra and Retherford 2007).

In simple regression, results reveal an excess risk associated with exposure to a high level of pollution. A multivariable regression used to adjust estimated risks, also reveals excess risk (AOR [95% CI]) in Benin (1.75 [1.39 - 2.20], Burkina Faso (3.21 [1.16 - 8.83]), Senegal (1.42 [1.05 - 1.92]), and in Togo (2.00 [1.11 - 3.62]. Other research that has also looked at this question has produced similar results. Biomass smoke exposes children to a high risk of stunting according to estimations (AOR [95% CI]) and those after controlling for various potential confounding factors: 1.50 [1.04 - 2.18](Dadras and Chapman 2017); 1.25 [1.08 - 1.44] (Kyu, Georgiades, and Boyle 2009). Moreover, parental tobacco use was also associated with an increased risk of stunting: 1.17 [1.12–1.21](Best et al. 2007); 1.58 [1.06-2.35](Dadras and Chapman 2017). Furthermore, although the approachesdiffer, ourresults point in the same direction as those of Lamichhaneand al.Risks estimated by the latter vary between 1.48 [1.16 - 1.89] and 2.81 [2.36 - 3.36](Lamichhane, Leem, and Kim 2020).

This study has a number of limitations. This is a cross-sectional study that does not allow a conclusion to be drawn on the causal relationship between the exposure factor and the dependent variable because the design does not take into account the temporality of events. In addition, the survey participants themselves report the information of interest, therefore, it is difficult to eliminate certain biases, especially those relating to the declaration. In addition, data used is not collected during same period, making it difficult to compare countries. However, the DHS remains currently one of the most well-developed primary sources of demographic and health data globally.

V. CONCLUSION

Indoor air pollution is a risk factor for occurrence of stunting in children under 5 years old and must be taken into account in interventions aimed at reducing the high burden of morbidity and mortality associated with it as well as in the causal analysis model of malnutrition. The DHS could also be interested in other factors of degradation of indoor air as well as in a metrology of indoor air in order to characterize it.

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AVAILABILITY OF DATA AND MATERIALS

Data used for this paper are accessible to researchers on condition of briefly explaining the purpose for it use. Details of the access conditions are available at the DHS program-http: //dhsprogram.com address.

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