Household Smoke-Exposure Risks from Cooking Fuels and Cooking Places in Tanzania: A Cross-sectional Study

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Keywords: indoor cooking, outdoor cooking, smoke producing cooking fuel, smoke exposure risk, Tanzania

Posted Date: November 18th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-106424/v1

Abstract

Background: Household smoke-exposure risk (SER) can be defined using cooking fuels (smoke and no smoke-producing) and cooking places (indoor and outdoor), which represents different levels of household air pollution. The study explored the prevalence and geographical variation of smoke-exposure risks (SERs) resulting from indoor and outdoor cooking practices using smoke-producing and no smoke-producing cooking fuels in Tanzania. We further investigated social and spatial factors associated with different levels of SER.

Methods: We constructed an indicator variable, the household SER, using country-level cross-sectional data on cooking fuels and places from 2015–16 Tanzania Demographic and Health Survey, and estimated zone-level average SERs. An ordered logistic regression model was employed to assess the social and spatial characteristics associated with household SER.

Results: Approximately 76.4% of total 12,425 households that practiced indoor cooking using smoke-producing fuels were at high SER. High-level SER was more prevalent in the Central, Southern highlights, and Southwest highlands zones. Overall, wealthier households, female-headed households, and having higher education levels among household members were more likely to be in very low SER category. However, older household heads and larger family sizes were less likely to be in very low SER category.

Conclusions: The significant prevalence of high smoke-exposure risk is a major public health concern in Tanzania, which requires simultaneous adoption of improved cooking stoves and clean fuels to minimize the adverse effects attributed to household SER.

Background

Globally, household air pollution remains a major health risk; it is estimated that 3.8 million people die prematurely every year from indoor air pollution illnesses resulting from the use of unclean cooking fuels and consequent household smoke-exposure (1). In sub-Saharan African countries, the prevalence of household air pollution is very high, due to the dependence on cheaply available biomass and solid cooking fuels (e.g., wood, charcoal) (2, 3), so the risk of smoke exposure remains. In Tanzania, burning biomass and solid fuels generally leads to both indoor and outdoor air pollution, the fourth-largest cause of different air pollution-related diseases (4).

In both rural and urban Tanzania, households' main sources of cooking fuel are wood (~ 66%) and charcoal (~ 27%), because of their availability and low cost (5). Only about 3% of households use bottled gas (5). The use of electricity among rural households is also very low, at nearly 2% (6). As the majority of households use smoke-producing cooking fuels, roughly 97% of households (on average, 67% of rural and 30% of urban households) are exposed to high levels of smoke due to indoor cooking. Several noncommunicable diseases, including stroke, heart disease, and lung cancer are caused by household air pollution, one of the top risk factors for morbidity and mortality in Tanzania (7). Approximately 60 deaths per 100,000 Tanzanian people in 2016 were attributed to household air pollution (8).

Different sociodemographic, economic, and spatial factors have been linked to household air pollution and consequent health impacts associated with cooking fuels in sub-Saharan African countries. Factors such as age, sex, education, socioeconomic status, and place of residence have been reported to have a relationship with the effects of both indoor and outdoor smoke pollution (3, 4, 9–12). Given that 76.4% of households in Tanzania cook indoors using smoke-producing fuels (5), it is important to understand the prevalence, geographical distributions, and factors associated with household smoke-exposure risks (SERs) in association with the use of certain cooking places and cooking fuels. However, existing studies are limited to examining either cooking fuels or cooking places in rural areas, and there is a paucity of research considering the different levels of household SERs.

Understanding the prevalence of SERs, their geographical variations, and their associated factors is particularly important in the work of public health researchers and policymakers, because of the high risk of poor household health in association with smoke-exposure and the consequent national impacts that may result from this poor degree of health. Therefore, we constructed four different levels of household SERs based on households' cooking places and cooking fuels using cross-sectional survey data of Tanzania, and we used sociodemographic and geographical characteristics to compare SER prevalence rates among rural and urban households. We further examined social and spatial factors of SERs associated with indoor and outdoor cooking using smoke- and no smoke-producing cooking fuels in rural and urban Tanzania.

Methods

Data

The present study used data from the nationally representative 2015–16 Tanzania Demographic and Health Survey (TDHS), which employed a two-stage stratified random sampling technique to select the household samples. First, a total of 608 sample points (clusters) were selected randomly, representing enumeration areas from 25 regions from the Tanzania mainland and five regions from Zanzibar, for a selection of 13,376 households (average 20 from each of the 608 clusters). Then, 8,929 households from 428 rural clusters and 3,634 households from 180 urban clusters were selected. Finally, through interviews, a total of 12,563 responses were recorded from 12,767 occupied households. Further details on the survey design and questionnaire can be found in the 2015–16 TDHS report (5).

Construction Of Household Smoke-exposure Risk (ser)

The outcome variable of our study was an ordered categorical variable that represented four different levels of smoke-exposure risks associated with household cooking fuels and cooking places. First, we categorized cooking fuel type as either "smoke-producing fuel" or "no smoke-producing fuel." Smoke-producing cooking fuels included kerosene, charcoal, wood, straw, shrubs, grass, animal dung, and others. Electricity and bottled gas were categorized as no smoke-producing cooking fuels. The second variable represented the household's cooking places. Households who cooked inside their houses or inside a separate building were categorized as "indoor cooking place" households, while households who reported using outdoor cooking places were categorized as "outdoor cooking place" households. Details on both Stata Do-file and R script regarding SER construction will be available in the Harvard Dataverse repository. Households who cooked no food in the house or used "other" cooking places were not considered in our analysis (13).

The combination of cooking fuel with cooking place produced an ordinal variable regarding SER, which was categorized into 'four' different levels of subjective risk: high-level (indoor cooking using smoke-producing fuels), medium-level (outdoor cooking using smoke-producing fuels), low-level (indoor cooking using no smoke-producing fuels), and very low-level (outdoor cooking using no smoke-producing fuels). SER was used to reveal the odds of a household identified as a lower-level smoke-exposure in a household. There were two underlying reasons for identifying these subjective risk levels (5). First, cooking with smoke-producing fuels is generally more dangerous to human health than cooking with no smoke-producing fuels. Second, we can also assume that using an indoor cooking place is more harmful than using an outdoor one, due to the potential for greater exposure to smoke during cooking as a result of the area being enclosed.

Visualization Of Ser

We calculated cluster-level prevalence of average household smoke-exposure risk by rural and urban survey zones in Tanzania. Rural and urban survey zones consisted of 428 and 180 clusters, respectively. As the exact locations of the surveyed households were readjusted to keep them anonymous, existing household data only presents zone and cluster numbers. Therefore, we calculated the average household SER of each cluster, where each cluster consisted of 20 to 22 households.

Respective shape file was collected from www.data.humdata.org. A cluster was donated as a color-coded dot on the map that represents the average SER level of a cluster. A dot represents average SER value, which each included 20 to 22 households. We used three color-coded dots to present average values of SER, such as yellow (if 1 or less than 1), green (if greater than 1 but less than 2), and red (if 2 and more). High SER indicates a higher level of average risk of smoke exposure. We visualized rural and urban-level average household SERs through QGIS version 3.8.3 (14).

Predictor Variables

We used a set of categorical independent variables—for example, household head's sex, age, highest educational attainment, family size, livelihood status (i.e., wealth index), and geographical location (i.e., survey zone)—in combination with total household health expenditure to understand the association with different levels of SER in the regression model.

The participants' responses about whether they currently spend money on their health were included. We also included the sex (i.e., male, female) of the household head. The age of the household head was categorized into four broad categories (i.e., 15–34 years, 35–54 years, 55–74 years, and 75–94 years). The household's highest educational attainment level was also categorized as no education, incomplete primary, complete primary but incomplete secondary, complete secondary, and higher than secondary. Family size was grouped into four broad categories, according to the number of members, as one member, 2–5 members, 6–10 members, and 11–49 members. Households' livelihood status was represented by five wealth quintiles (i.e., poorest, poor, medium, richer, and richest), retrieved from the wealth index. In general, wealth index is considered to be a proxy of a household's livelihood status and noncomparable to the wealth index values of any other country. Geographical characteristics were presented by nine survey zones (i.e., Western, Northern, Central, Southern highlands, Southern, Southwest highlands, Lake, Eastern, and Zanzibar) and two residence area types (i.e., rural and urban).

Statistical analysis

Descriptive statistics of the outcome and predictor variables were calculated using the recommended sample weight, which present unweighted numbers and weighted percentages. We then regressed the household SER onto a household's social and spatial characteristics. As different sociodemographic and economic characteristics are considered to be associated with a household's selection of cooking places and fuels, we included previously mentioned predictor variables (i.e., health expenditure, sex of household head, age group of household head, household's educational attainment, family size, wealth index, and survey zone). We also included a zone-level variable to predict any association between SER and regional attribute. Ordered logistic regression models were used to estimate the odds ratios (ORs) for all three models (i.e., primarily focused on combined rural and urban as national, and rural, and urban as a secondary focus) with 95% confidence intervals (CIs) of the factors of household SER in Tanzania.

All descriptive and statistical analyses were carried out in Stata version 16.1 (15). DHS Program of ICF International, Fairfax, VA, USA approved data access for the study. Intuitional review board approval was not sought for this analysis because we used deidentified and publicly available 2015–16 TDHS data for analyses.

Results

Among 12,425 surveyed rural and urban households, 76.4% (95% Confidence Interval (CI): 74.56–78.12) of households reported practicing indoor cooking with smoke-producing cooking fuel, thus falling under a high SER household category in the present study (Table 1). Medium and low SER households, respectively, comprised 20.2% (95% CI: 18.68–21.77) and 3.3% (95% CI: 2.38–4.52) of the total survey population. Only 0.1% (95% CI: 0.00–0.25) of households reported cooking outside using no smoke-producing fuels (i.e., very low household SER category).

Table 1
Prevalence of household smoke-exposure risks (SERs) in Tanzania.

Cooking practice		Level of household SER[a]	National (n = 12,425) % (95% CI)	Rural (n = 8,870) % (95% CI)	Urban (n = 3,555) % (95% CI)
Cooking fuel	Cooking place				
Smoke-producing	Indoor	High	76.4 (74.56–78.12)	84.3 (82.36–85.97)	60.1 (56.62–63.55)
Smoke-producing	Outdoor	Medium	20.2 (18.68–21.77)	15.1 (13.43–16.97)	30.6 (27.83–33.61)
No smoke-producing	Indoor	Low	3.3 (2.38–4.52)	0.6 (0.40–0.90)	8.8 (6.22–12.43)
No smoke-producing	Outdoor	Very low	0.1 (0.00-0.25)	0.03 (0.00-0.14)	0.4 (0.21–0.70)

Abbreviations: n, number of observations; HH, household

[a]The level of smoke-exposure risk (SER) is a “subjective risk” established in terms of the expected SER associated with cooking fuels and cooking places. All percentage (%) values are weighted. Households who used smoke-producing fuels were found to be more exposed to cooking smoke than those who used no smoke-producing fuels. Similarly, exposure to cooking smoke was greater among households who cooked indoors than outdoors.

We also noted the existence of geographical variations in household SER prevalence. The prevalence of a high SER was greater in rural areas (84.3%) than in urban areas (60.1%); however, medium and low SERs were more prevalent in urban areas (30.6% and 8.8%) than in rural areas (15.1% and 0.6%). Figure 1 depicts rural–urban heterogeneity according to the prevalence rates of different levels of SER. Overall, the patterns of variation in SER prevalence rates across zones were similar between rural and urban areas. Notably, both rural and urban Central zones had some of the high-level SER households. In Zanzibar, relatively little variation was seen between rural and urban households; however, such differences were more pronounced among other survey zones. The differences in prevalence rates of medium, low, and very low SERs among rural and urban areas were generally very low and sometimes indistinct. The surveyed households’ sociodemographic, economic, and spatial characteristics are presented in Table 2.

Table 2
Sociodemographic and economic characteristics by zone and household smoke-exposure risk (SER) categories in Tanzania.

Variable	Area[a]			SER[b]			
	National[c] (n, %)	Rural (n, %)	Urban (n, %)	High (%)	Medium (%)	Low (%)	Very low (%)
Health expenditure							
No	10,612 (84.5)	7,606 (85.2)	3,006 (82.7)	76.8	19.9	3.1	0.1
Yes	1,951 (15.5)	1,323 (14.8)	628 (17.3)	73.9	21.6	4.3	0.3
Sex of HH head							
Male	9,500 (75.6)	6,785 (76.0)	2,715 (74.7)	77.1	19.5	3.3	0.1
Female	3,063 (24.4)	2,144 (24.0)	919 (25.3)	74.3	22.2	3.4	0.2
Age group of HH head							
15–34 years	3,399 (27.1)	2,177 (24.4)	1,222 (33.7)	70.1	24.9	4.6	0.4
35–54 years	5,637 (45.0)	3,988 (44.7)	1,649 (45.4)	76.5	20.3	3.2	0.1
55–74 years	2,856 (22.8)	2,183 (24.5)	673 (18.5)	81.7	15.6	2.6	0.1
75–94 years	652 (5.2)	565 (6.3)	87 (2.4)	86.4	13.4	0.3	0.0
Education							
No education	594 (4.7)	525 (5.9)	69 (1.9)	82.5	17.5	0.0	0.0
Incomplete primary	1,564 (12.5)	1,337 (15.0)	227 (6.3)	82.7	17.1	0.2	0.0
Complete primary	5,448 (43.4)	4,279 (47.9)	1,169 (32.2)	79.3	20.0	0.7	0.1

Abbreviations: n, number of observations; HH, household

[a]Includes unweighted observations (n) and respective percentage (%) values. [b]Includes weighted percentage (%) values. [c]Includes both rural and urban households' data.

Variable	Area[a]			SER[b]			
	National[c] (n, %)	Rural (n, %)	Urban (n, %)	High (%)	Medium (%)	Low (%)	Very low (%)
Incomplete secondary	1,917 (15.3)	1,331 (14.9)	586 (16.1)	76.1	22.6	1.2	0.1
Complete secondary	2,594 (20.7)	1,346 (15.1)	1,248 (34.3)	69.3	22.8	7.5	0.4
Higher	446 (3.6)	111 (1.2)	335 (9.2)	51.0	14.6	33.4	1.0
Family size							
1 member	1,029 (8.2)	596 (6.7)	433 (11.9)	66.8	25.6	7.3	0.3
2–5 members	6,633 (52.8)	4,594 (51.5)	2,039 (56.1)	74.8	21.4	3.6	0.2
6–10 members	4,276 (34.0)	3,236 (36.2)	1,040 (28.6)	80.4	17.4	2.1	0.1
11–49 members	625 (5.0)	503 (5.6)	122 (3.4)	83.4	15.8	0.9	0.0
Wealth index							
Poorest	1,992 (15.9)	1,856 (20.8)	136 (3.7)	87.1	12.9	0.0	0.0
Poor	2,288 (18.2)	2,207 (24.7)	81 (2.2)	85.2	14.8	0.0	0.0
Middle	2,560 (20.4)	2,332 (26.1)	228 (6.3)	81.5	18.5	0.0	0.0
Richer	2,973 (23.7)	1,896 (21.2)	1,077 (29.6)	75.7	23.7	0.6	0.0
Richest	2,750 (21.9)	638 (7.2)	2,112 (58.1)	57.0	28.5	14.0	0.6
Survey zone							
Western	858 (6.8)	668 (7.5)	190 (5.2)	84.9	14.1	0.9	0.1
Northern	1,293 (10.3)	917 (10.3)	376 (10.4)	76.9	16.4	6.4	0.3
Central	1,284 (10.2)	1,036 (11.6)	248 (6.8)	88.0	11.4	0.7	0.0

Abbreviations: n, number of observations; HH, household

[a]Includes unweighted observations (n) and respective percentage (%) values. [b]Includes weighted percentage (%) values. [c]Includes both rural and urban households' data.

Variable	Area[a]			SER[b]			
	National[c] (n, %)	Rural (n, %)	Urban (n, %)	High (%)	Medium (%)	Low (%)	Very low (%)
Southern highlands	1,255 (10.0)	911 (10.2)	344 (9.5)	85.0	13.3	1.6	0.1
Southern	833 (6.6)	632 (7.1)	201 (5.5)	73.9	24.9	1.2	0.0
South west highlands	1,247 (9.9)	867 (9.7)	380 (10.5)	85.2	12.8	2.0	0.0
Lake	2,555 (20.3)	1,984 (22.2)	571 (15.7)	76.1	22.7	1.1	0.2
Eastern	1,483 (11.8)	528 (5.9)	955 (26.3)	56.5	34.2	9.2	0.3
Zanzibar	1,755 (14.0)	1,386 (15.5)	369 (10.2)	79.0	17.1	3.6	0.4
Abbreviations: n, number of observations; HH, household							
[a]Includes unweighted observations (n) and respective percentage (%) values. [b]Includes weighted percentage (%) values. [c]Includes both rural and urban households' data.							

From regression analyses, we found that families with a female head, a higher educational level attained, higher livelihood status (i.e., higher wealth quintile), and living in the Eastern zone were associated with a higher odds (i.e., positive association) of being very low SER household category at the national level (Table 3). The associations and magnitudes of the estimates for rural and urban households were more or less similar to those estimated among combined (as national) households, except for the level of statistical significance. For female-headed households, the odds (Odds ratio (OR): 1.3, 95% CI: 1.14–1.48) of being very low SER household was high relative to male-headed households. Among urban households, this relationship (OR: 1.4, 95% CI: 1.14–1.66) was also significant; meanwhile, the results for rural areas were statistically insignificant. Households with a higher educational level attainment (OR = 3.4, 95% CI: 1.93–5.87) had higher odds to be very low SER households relative to those without any educational attainment, with a similar but stronger association for households in urban areas recorded. Further, middle (OR: 1.4, 95% CI: 1.07–1.82), richer (OR: 1.7, 95% CI: 1.28–2.18), and richest (OR: 3.3, 95% CI: 2.51–4.43) households had the high odds of being low SER households when compared with the other household categories combinedly; however, the distinction between rural and urban households was not very significant. Households in the Eastern zone, irrespective of being in a national, rural, or urban area, had high odds to be very low SER households when compared to those in the Western zone.

Table 3
Social and spatial predictors of household smoke-exposure risks (SERs) in Tanzania.

Variable	National[a] (n = 12,406)		Rural (n = 8,854)		Urban (n = 3,552)	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Health expenditure						
No	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
Yes	1.1 (0.95–1.33)	0.159	1.0 (0.78–1.24)	0.897	1.3 (0.99–1.59)	0.056
Sex of HH head						
Male	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
Female	1.3 (1.14–1.48)	0.000	1.1 (0.95–1.36)	0.169	1.4 (1.14–1.66)	0.001
Age group of HH head						
15–34 years	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
35–54 years	0.8 (0.70–0.92)	0.002	0.7 (0.63–0.89)	0.001	0.9 (0.73–1.08)	0.224
55–74 years	0.6 (0.50–0.72)	0.000	0.6 (0.49–0.74)	0.000	0.6 (0.45–0.83)	0.002
75–94 years	0.5 (0.38–0.71)	0.000	0.6 (0.39–0.81)	0.002	0.4 (0.21–0.8)	0.009
Education						
No education	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
Incomplete primary	1.1 (0.77–1.44)	0.754	1.0 (0.69–1.43)	0.966	1.5 (0.74–2.91)	0.268
Complete primary	1.1 (0.79–1.46)	0.669	1.1 (0.74–1.53)	0.725	1.4 (0.72–2.57)	0.339
Incomplete secondary	1.1 (0.75–1.53)	0.702	1.0 (0.62–1.51)	0.871	1.5 (0.76–3.01)	0.242

Abbreviations: number of observations; OR,odds ratio; CI,confidence interval; n, p value, probability value; Ref, reference category.

[a]Includes both rural and urban households’ data.

Variable	National[a] (n = 12,406)		Rural (n = 8,854)		Urban (n = 3,552)	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Complete secondary	1.2 (0.84–1.71)	0.309	1 (0.64–1.43)	0.822	1.8 (0.91–3.64)	0.090
Higher	3.4 (1.93–5.87)	0.000	1.2 (0.58–2.37)	0.662	5.8 (2.69–12.72)	0.000
Family size						
1 member	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
2–5 members	0.7 (0.56–0.83)	0.000	0.7 (0.52–0.91)	0.009	0.7 (0.52–0.91)	0.009
6–10 members	0.6 (0.44–0.69)	0.000	0.6 (0.47–0.88)	0.006	0.5 (0.34–0.67)	0.000
11–49 members	0.5 (0.34–0.67)	0.000	0.4 (0.29–0.68)	0.000	0.6 (0.35–1.06)	0.081
Wealth index						
Poorest	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
Poor	1.1 (0.82–1.37)	0.670	1.1 (0.83–1.42)	0.532	0.8 (0.25–2.82)	0.766
Middle	1.4 (1.07–1.82)	0.014	1.3 (0.95–1.7)	0.106	2.5 (1.16–5.35)	0.020
Richer	1.7 (1.28–2.18)	0.000	1.2 (0.89–1.7)	0.209	1.8 (0.89–3.49)	0.105
Richest	3.3 (2.51–4.43)	0.000	3.4 (2.28–5.15)	0.000	2.4 (1.2–4.89)	0.014
Survey zone						
Western	1.0 (Ref)		1.0 (Ref)		1.0 (Ref)	
Northern	1.3 (0.83–1.94)	0.276	1.4 (0.78–2.35)	0.277	1.2 (0.66–2.12)	0.565
Central	0.8 (0.50–1.17)	0.213	1.0 (0.55–1.69)	0.891	0.5 (0.3–0.84)	0.009

Abbreviations: number of observations; OR,odds ratio; CI,confidence interval; n, p value, probability value; Ref, reference category.

[a]Includes both rural and urban households’ data.

Variable	National[a] (n = 12,406)		Rural (n = 8,854)		Urban (n = 3,552)	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Southern highlands	0.7 (0.48–1.15)	0.177	1.0 (0.51–1.84)	0.926	0.5 (0.33–0.78)	0.002
Southern	1.8 (1.17–2.85)	0.008	1.7 (0.91–3.09)	0.099	2.0 (1.33–3.04)	0.001
South west highlands	0.8 (0.48–1.30)	0.343	1.0 (0.49–1.96)	0.951	0.5 (0.27–0.93)	0.030
Lake	1.6 (1.12–2.35)	0.010	1.7 (1.05–2.85)	0.032	1.5 (0.98–2.19)	0.060
Eastern	2.5 (1.69–3.64)	0.000	3.6 (2.06–6.27)	0.000	1.6 (1.05–2.36)	0.029
Zanzibar	0.9 (0.58–1.38)	0.612	1.5 (0.84–2.62)	0.174	0.5 (0.25–0.95)	0.035

Abbreviations: number of observations; OR,odds ratio; CI,confidence interval; n, p value, probability value; Ref, reference category.

[a]Includes both rural and urban households' data.

We also found that more aged household heads and a higher number of family members were associated with lower odds (i.e., negative association) of very low SER household. Overall, households with household heads aged 35 to 94 years had the lowest odds of being very low SER households, which was similarly found among rural households. In general, the odds of being a very low SER household versus the combined categories of other SER categories were 0.8 times (95% CI: 0.70–0.91) lower among households with heads aged 35 to 54 years, 0.6 times (95% CI: 0.50–0.72) lower among households with heads aged 55 to 74 years, and 0.5 times (95% CI: 0.38–0.71) lower among households with heads aged 75 to 94 years when compared to those aged 15 to 34 years old. Similarly, a household with more family members in this study had lower odds of being a very low SER household. Overall, the odds of being a very low SER household versus the combined categories of remaining SER categories were 0.7 times (95% CI: 0.56–0.83) lower among households with two to five members, 0.6 times (95% CI: 0.44–0.69) lower among households with six to 10 members, and 0.5 times (95% CI: 0.34–0.67) lower among households with 11 to 49 members when compared with single-member households. Similar to what was seen with household educational attainment level, the estimated results for both rural and urban households were almost similar, except the level of statistical significance.

We observed no association between health expenditure and SER, when considering national, rural, and urban areas. In most cases, the association between survey areas and SER were not evident at the national, rural, and urban levels, except Eastern zone (Table 3). Similar statistically insignificant results were evident between education and Ser, especially for the first four categories of educational attainment (e.g., incomplete primary, complete primary, incomplete secondary, and completer secondary).

Discussion

To the best of our knowledge, this is the first country-level study to construct different levels of household smoke-exposure risk based on households' indoor and outdoor cooking places and smoke-producing and no smoke-producing cooking fuels using cross-sectional survey data. Our study found that a high percentage of households in Tanzania were categorized as high SER households who practiced indoor cooking with smoke-producing cooking fuels. Overall, households headed by females, higher educational level attained, higher livelihood status, and living in the Eastern zone were associated with a higher probability of being very low SER households. In contrast, having a more aged household head and having a greater number of family members were associated with a low probability of being a very low SER household. In most cases, the estimated relationships were similar between rural and urban households.

In the study, almost three-fourth of Tanzanian households were categorized as high SER household due to their indoor cooking practices using smoke-producing fuels, and the prevalence of these was higher in rural areas than in urban areas. The main source of cooking fuel in Tanzania is smoke-producing, unclean biomass (4), which is also commonly used in other sub-Saharan African countries (16). As clean fuel is often not available or is costly when available, households mostly adopt cheap, available fuel sources such as wood for daily cooking instead (17). Also, 45% of Tanzanian households cooked in a separate space, 45% of the households still used their home as a cooking place. These prevalence were expected, given that 49.1% of the total population in Tanzania lives below the poverty line. It would be practically impossible to influence them to establish a separate cooking place and adopt clean fuels like charcoal and bottled gas (18). Instead, conducting open cooking practices under an overhang without closed walls, using wood or charcoal, would be a feasible option by which to reduce the SER level in many rural areas, although we also need to consider what other options (e.g., bioethanol) are feasible. Thus, their limited ability to purchase clean fuels as well as these fuels' unavailability might influence the adoption of cooking with smoke-producing fuels and the likelihood of being a high SER household.

The use of traditional but inefficient cooking stoves is another reason for household air pollution (19). Sometimes, seasonality affects the method of cooking adopted. For example, outdoor cooking may be impossible during rainy or cold seasons (20–22). In these cases, indoor cooking might also be made less risky with proper ventilation, which has important implications in reducing household smoke-exposure risk. Prospective research considering indoor and outdoor SERs could shed light on seasonal cooking practices, including the geographical availability of clean fuels. Cluster-level data on clean fuel availability or proximity to the nearest shop are important to gather to understand area-based cooking fuel availability and access.

Education is important for the adoption of cleaner or no smoke-producing cooking fuels and safe cooking practices, because in most cases, it generates awareness about the potential negative health impacts of indoor smoke on overall household health (17, 23). In our study, we observed that households with a higher educational attainment were more likely to be very low SER households. This finding suggests that households with high educational attainment levels more often practice outdoor cooking using cleaner cooking fuels (24). An awareness program or short health education intervention initiative might be a policy option in Tanzania for reducing risky cooking practices to minimize the SER level and in promoting the adoption of safe cooking practices that involve using properly ventilated cooking places and clean fuels (25).

We observed geographical variations in SER levels. Most of the zones surveyed had a high prevalence of high SER; however, households in the Eastern zone were more often categorized as low-risk households. In the Eastern zone, 34.5% of households cooked outdoors, and 9.4% of households used no smoke-producing fuels. The geographical disparity in outdoor cooking using no smoke-producing fuels is also linked with variations in economic disparity level by zone. We found that almost 53.3% of the households in the Eastern zone were categorized as the richest households. The use of clean fuel depends on the access to and availability of clean fuels, and this might be a possible reason why there is a high percentage of households who use no smoke-producing fuel in this area. The high percentage of outdoor cooking practices in this zone was also associated with a low prevalence of low household SER.

Joint public-private initiatives like “Clean Air Initiative of Sub-Saharan Africa,” “Promoting Bio-Ethanol as a Clean Alternative Fuel for Cooking in Tanzania,” “Clean Cookstoves and Fuels Alliance of Tanzania” program are important for Tanzania’s national progress (26). However, the risk and burden of household smoke exposure and the consequent public health issues attributed to air pollution can certainly be reduced by a gradual transition to efficient cooking stoves, in cases of low access to and a low availability of no smoke-producing fuels, and a greater adoption of clean fuels through regionally prioritized multisectoral (e.g., public health, energy, environment) development programs (19, 27). To do so, common market and non-market barriers (e.g., financing and marketing clean fuel-related infrastructures, public awareness and willingness to use for clean fuel) need to be considered through public-private partnerships to improve the scenarios (28).

Several concerns should be noted in the context of its limitations. First, the survey only recorded primary cooking fuel and place, and hence, households who used secondary cooking fuels and places were not identified or considered in our study. The use of multiple cooking fuels and places might affect the SER level, and weighted categorization would be the potential way to deal with this issue. Second, due to data limitations, the degree of smoke-exposure was unknown, which might also be associated with time spent performing cooking. Also, seasonality (e.g., rainy and dry seasons), weather (e.g., windy day or night), and the availability of cooking fuels during different seasons might be other combined factor that influences the household SER. Collecting related data on these events is essential for pursuing better-informed policy and decision-making. Finally, assessing the causal relationship between the outcome and predictor variables was not possible, as we used cross-sectional survey data. Multiyear cross-sectional data are required to identify any causal relationships between SER and possible predictor variables. Future studies will also benefit from gathering more details on cooking practices, such as time spent on cooking, the number of persons directly associated with cooking, and the use of different cooking fuels simultaneously, in investigating the degree of smoke-exposure risk.

Conclusions

Our findings suggest that the high prevalence of high smoke-exposure risk could be a major public health concern in Tanzania. It, therefore, requires simultaneous adoption of improved cooking stoves and clean fuels to minimize the adverse effects attributed to household smoke-exposure risks. Future program intervention targeting these issues should consider area and related socio-demographic factors to reduce the smoke exposure risks.

Abbreviations

CI: confidence interval; OR: Odds ratio; SER: smoke-exposure risk; TDHS: Tanzania demographic and health survey.

Declarations

Authors' contributions

MGA conceived the idea of the study and contributed to the study design. MGA and FT reviewed related literature to develop the research idea. MGA contributed to statistical analysis and wrote first draft of the manuscript. With technical supports from NS, MGA performed the visualization of spatial data. All authors edited several drafts to produce finally approved manuscript.

Funding

None.

Availability of data and materials

Request for publicly available 2015–16 TDHS data should be made at the DHS Program website (https://dhsprogram.com/data/). Details on Stata Do-file and R script regarding SER construction are available in the Harvard Dataverse repository (https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/5J4YZZ).

Ethics approval and consent to participate

Intuitional review board approval was not sought for this study because we used deidentified and publicly available 2015–16 TDHS data for analyses. DHS Program of ICF International, Fairfax, VA, USA approved data access for the study. Informed consent was obtained from each respondent by the interviewers during the initial surveys. Details ethical standards and data collection procedures and review documentations can be found at https://dhsprogram.com.

Consent for publication

Not applicable.

Competing interests

The authors report no conflict of interest, financial or otherwise.

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Figures

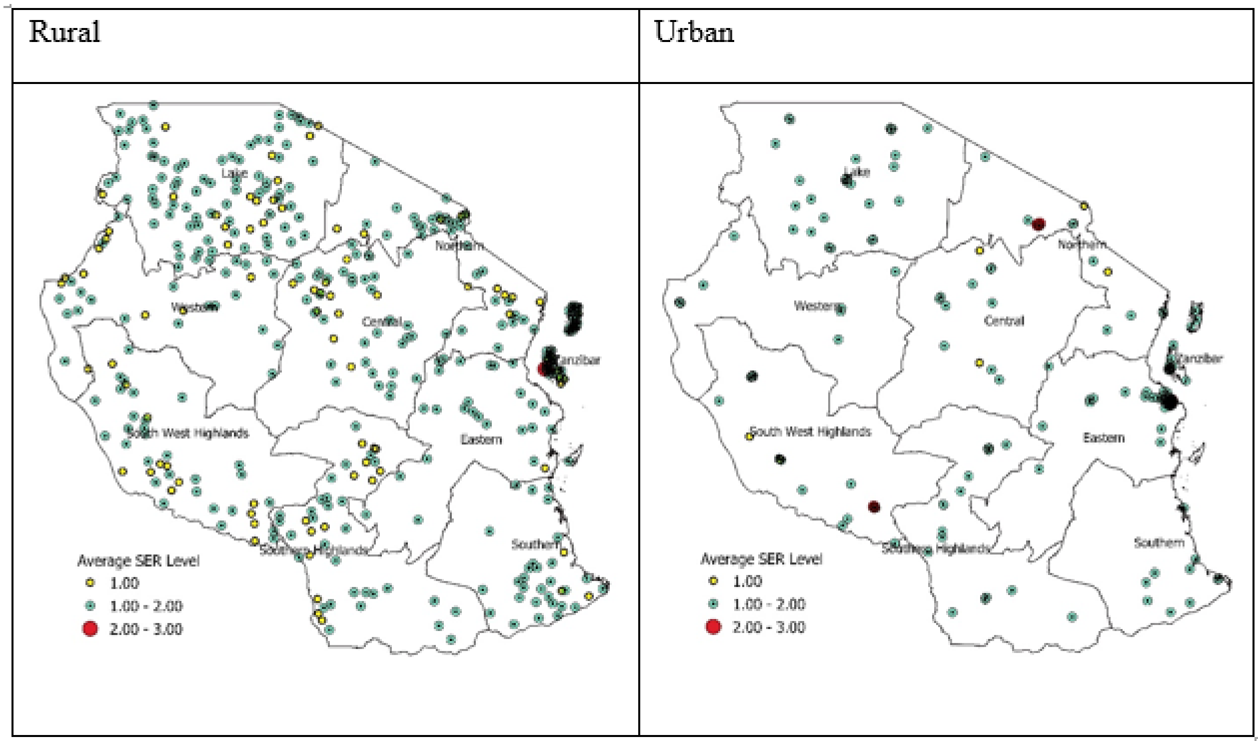
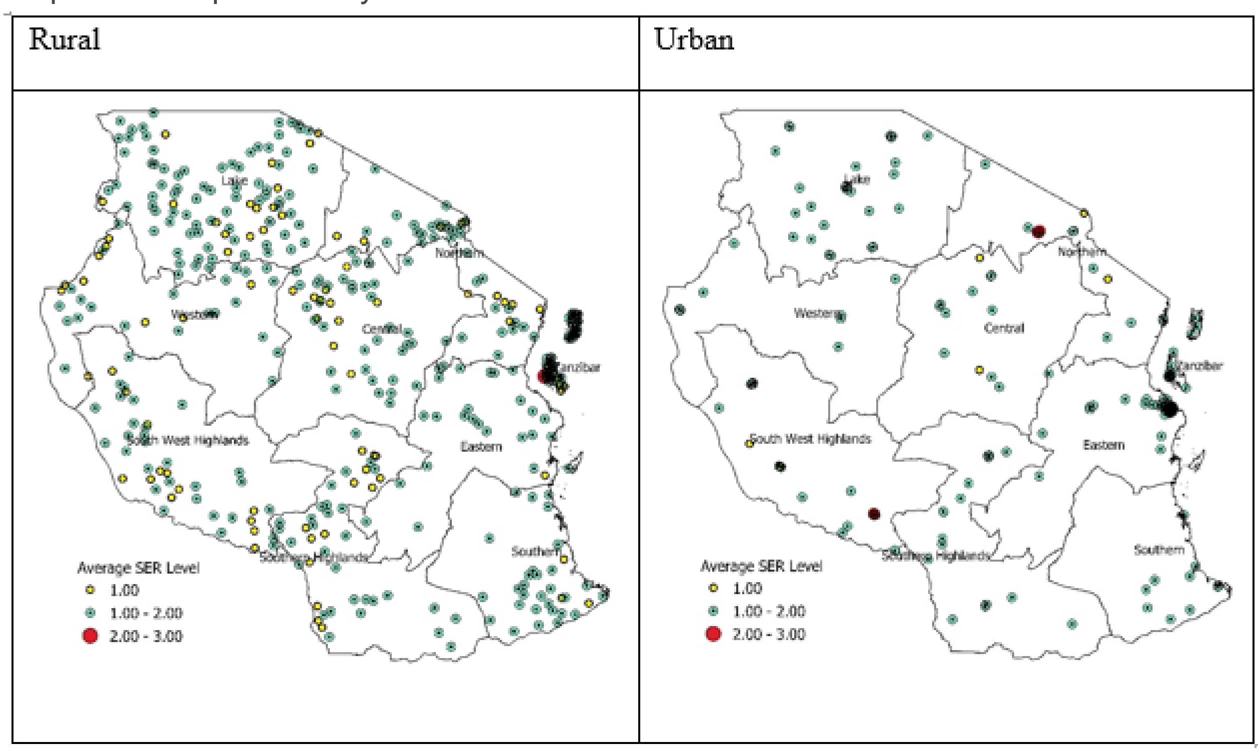


Figure 1

Cluster-level prevalence of average household smoke-exposure risk by survey zone in Tanzania. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



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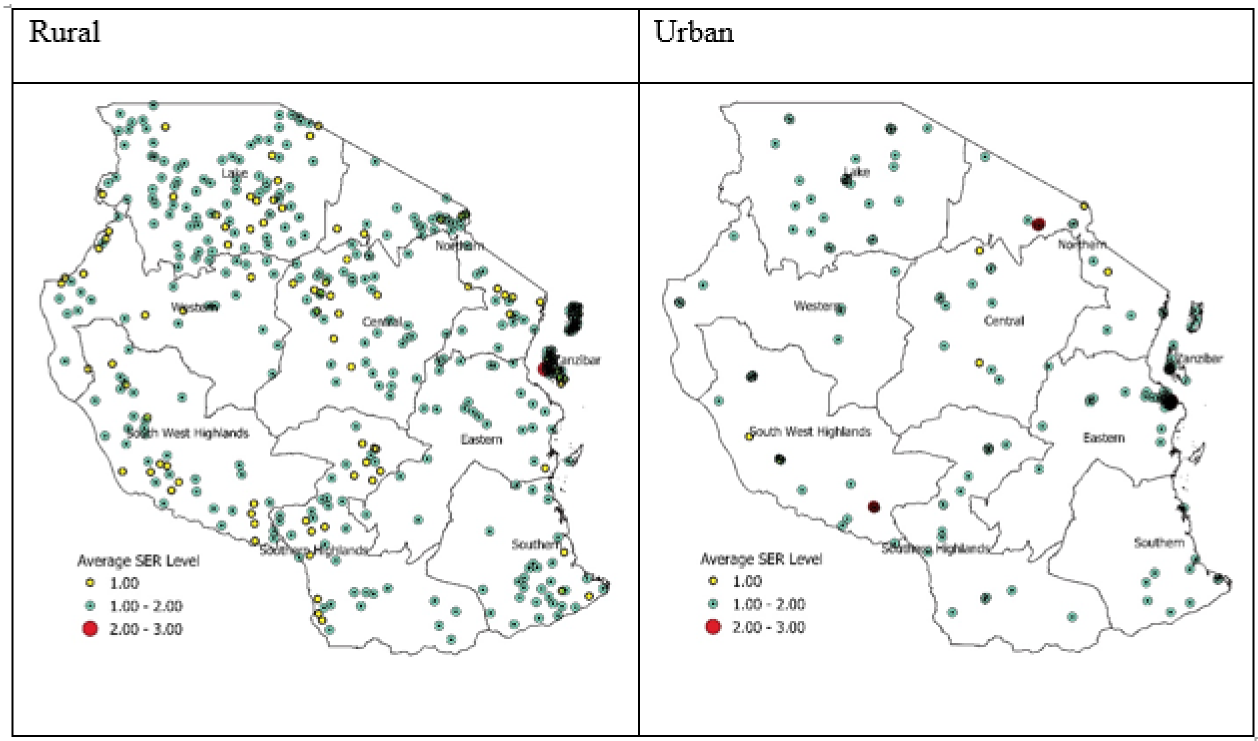

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