Household Solid Fuel Use and Associated Factors in Ethiopia: A Multilevel Analysis of Data From 2016 Ethiopian Demographic and Health Survey

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ABSTRACT: Solid fuels are types of fuel that comprise coal, biomass, charcoal, wood, or straw and are used for cooking, heating, lighting, boiling water, and generating revenue at home. Globally, 3 billion of the world's poorest people continue to rely on inefficient solid fuels, which produce health-damaging contaminants. In Ethiopia, more than 90% of households rely on wood as their primary source of energy. The actual and potential determinants of solid fuel use have not been fully identified, particularly at the national level in Ethiopia. Therefore, this study aimed to determine the magnitude of solid fuel use and its associated factors in Ethiopia. We used the Ethiopian Demographic and Health Survey (EDHS), which was conducted in 2016. The data was conducted using a 2-stage stratified cluster sampling approach. A total of 16 650 weighted samples were taken. Multilevel logistic regression models were fitted to identify factors associated with solid fuel use, and a cluster-level random intercept was introduced in the mixed model. An adjusted odds ratio with a 95% confidence level was reported to show the strength of the association and its significance. The goodness of fit of the model was checked using proportional change deviance (PCV). The magnitude of solid fuel use among households in Ethiopia was 94.03% (95% CI = 93.66, 94.37). Household heads completed in primary school (AOR, 3.09, 95% CI = 2.44, 3.91), outdoor cooking places (AOR, 4.13, 95% CI = 2.96, 5.76), and small peripheral regions (AOR, 14.44, 95% CI = 6.12, 34.04) were all significantly associated with solid fuel use. The intra-cluster correlation coefficient (ICC) showed that about 81% of the variations in the use of solid fuel were attributed to the difference at the 643 cluster level, but the remaining 19% were attributed to individual household factors. The PCV was 90%, which showed that the variation in solid fuel use among study households was explained by factors at both the individual and community levels. The deviation test of the fourth model had the lowest value (3528) and was chosen as the best-fitted model. Due to different influencing factors, the use of solid fuel is still high in Ethiopia. Promoting access to education and raising awareness toward solid fuel impact is very important.

KEYWORDS: Solid fuel, household, factors, EDHS, Ethiopia

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Introduction

Solid fuels are a form of fuel that comprises coal, biomass, charcoal, wood, or straw, animal dung, and crop wastes that are used for cooking, heating, lighting, boiling water, and generating revenue at home.[1,2] Solid fuels are still used by 3 billion of the world's poorest people, including wood, animal dung, charcoal, crop wastes, and coal. So, solid fuels are inefficient and result in high levels of household air pollution and it creates health-harming pollutants such as small soot particles that penetrate deep into the lungs.[3] The smoke contains toxic air chemicals such as carbon monoxide (CO) and carbon dioxide (CO_2), as well as other contaminants such as ashes and dust particles. These particles contribute to indoor air pollution and climate change.[4] Solid fuel use is most popular in Africa and Southeast Asia, where more than 60% of families cook with solid fuels.[5] More than 80% of the people in Sub-Saharan Africa rely on biomass fuel sources.[6] Ethiopian households rely heavily on solid fuels, with more than 90% relying on wood as their primary source of energy.[7] Approximately, 97% of households in Southern Ethiopia used wood for cooking.[8]

Traditional family energy habits have a far-reaching effect on health, the environment, and socioeconomic development. Every year, 4 million children and adults die prematurely as a result of respiratory, cardiovascular, and cancer diseases.[3] According to the WHO, almost 4 million people die prematurely each year due to exposure to domestic air pollution, with the entire burden of the disease outweighing the burden of outdoor air pollution by a factor of 5. This practice was

estimated to cause approximately 2 million premature deaths from pneumonia, chronic obstructive pulmonary disease, and lung cancer.[9] Household air pollution is estimated to be the cause of 3.5 million premature deaths worldwide, as well as cataracts and cardiovascular disease.[10] Indoor air pollution is estimated to be responsible for 3.7% of the overall burden of diseases among developing countries in 2004[11] and this figure was raised to 4% in 2008.[12] Different studies have linked solid fuel consumption to low birth weight,[13] acute respiratory infections in young children.[8] Inefficient burning of solid fuels contributes significantly to the release of climatic pollutants.[14]

According to several types of research, numerous factors contribute to the utilization of solid fuels. Among these are the age of the head of the household,[4] the level of household income,[4,5] the residences,[8] the educational status,[4,15] and the lack of access to modern energy.[10] Based on the literature, it has been suggested that households with low incomes rely on biomass fuels such as wood and dung, while those with higher incomes consume cleaner energy.[15] Larger family sizes and female-headed households may improve the likelihood of adopting solid fuels.[15]

The Ethiopian government has developed a promotion program for improved biomass cooking stoves to reduce solid fuel consumption and the rate of deforestation. The reduction in solid fuel use may lower the likelihood of negative health effects in children and adults. Despite the promotion, there is still significant use of solid fuels and susceptible groups, particularly women and children, due to indoor air pollution. Women carry their children on their backs while cooking, and children spend hours near the cooking fire with their mothers, exposing them to health-damaging toxins.[16] The time spent in harvesting biomass fuel and cooking has been shown to have a negative influence on schooling and development,[17] a disproportionate amount of household income is spent on acquiring it. Furthermore, the strong reliance on solid fuels has a substantial environmental impact, including deforestation and soil erosion.[4,15]

Therefore, this study aimed to identify the factors that influence the use of solid fuel in Ethiopia. The findings of this study aim to advance knowledge by identifying the various factors that influence the choice of energy. Most importantly, it is hoped that this study will prompt local and national governments, nonprofit organizations, and policymakers to implement appropriate policy measures and intervention programs to promote modern cooking energy consumption. Regarding this, it is assumed that any policy action aimed at influencing current home cooking energy choices must first identify the primary elements that contribute significantly to traditional fuel use.

Methods

We used data from the Ethiopian Demographic and Health Survey (EDHS), which was conducted in 2016 from January 18 to June 27,[18] which was carried out in 9 regions and 2 city administrations. The EDHS was created to offer representative statistics at the national and regional levels. It is the fourth conducted Demographic and Health Survey, which is carried out by the Central Statistical Agency (CSA). The data were collected using a 2-stage stratified cluster sampling approach.[19] The 2016 EDHS sample was divided into urban and rural areas and was chosen in 2 stages. In the first step, 645 enumeration areas (202 in urban regions and 443 in rural areas) were selected in proportion to the size of the enumeration area. The second stage involved selecting a fixed number of 28 households per cluster with an equal probability of systematic selection. But, only 643 clusters were used due to the missing of 2 clusters. The total weighted sample size for analysis was 16 650. Before using the EDHS dataset, it must be weighted to restore the representativeness of the sample. We used households (HR file) or household weight variable (hv005) multiplied by the inverse of the household response rate for a household in the stratum. Household sample weights are generated by dividing (hv005) by 1 000 000 before use to approximate the number of cases. The EDHS data set was downloaded from the DHS website (http://www.measuredhs.com). Handling of missing values were based on, the EDHS guideline data set the outcome variable had no missing values. By default, our variables had no missing value rather they had a "do not know" type of option for minor variables and it was included.

Study Variables

Outcome variable

The outcome variable for this study was the use of solid fuel, "solid/non-solid." During the survey, coal/lignite, charcoal, wood, straw/shrub/grass, crops, animal dung, electricity, liquefied petroleum gas (LPG), natural gas, and biogas were all types of cooking fuel mentioned in the responses of household heads. The outcome variables were constructed based on the EDHS data response categories such as coal/lignite, charcoal, wood, straw/shrub/grass, crops, and animal dung were combined and coded as "solid fuel use" (coded as "1") and as well as categories such as electricity, liquefied petroleum gas (LPG), natural gas, and biogas were combined and coded as "no solid/clean fuel use" (coded as "0").

Explanatory variables

The following factors were investigated to assess the factors associated with the reported use of solid fuel. (i) Sociodemographic characteristics such as the age of the head of household, the sex of the head of household, the marital status of the head of household, the educational status of the head of household, the wealth index, the size of the household, access to electricity, access to water, and the place of cooking food. (ii) Community-level factors such as residence, region, media exposure, as well as community-level education and poverty,

Table 1. Explanatoy variables which were extracted from the DHS data set for studying solid fuel use in Ethiopia.

VARIABLES	DEFINITION	CATEGORIES
Age	The age of the household head in years at the time of the survey	1. <18 2. 18-30 3. 31-45 4. 46-65 5. >66
Sex	The sex of the household head	1 Male 2 Female
Household head Education	The highest educational level the household head attained at the time of survey (Those participants with no education, attained preschool and do not know was classified under "**No formal education**," (Primary as "Primary"), and who attended secondary and higher as" **Secondary and** higher"	0. No formal education 1. Primary 2. Secondary and higher
Marital status	Marital status of the household head at the time of survey	0. Never married 1. Married 2. Widowed 3. Divorced
Household variables extracted from DHS		
Wealth index	EDHS categories were given based on the number and kinds of consumer goods the households owned ranging from a television to a bicycle or car, in addition to housing characteristics such as a source of drinking water, toilet facilities, and flooring materials. We recategorized the poorest and poorer households were categorized under "**Poor**" wealth status, middle as "**Middle**" wealth status, and those richer and richest were categorized under "**Rich**" households.	0. Poor 1. Middle 2. Rich
Household size	The number of household members with which the household head was living.	0. <2 1. 3-4 2. >5
Region	The geographical region of Ethiopia where household heads live. Tigray, Amhara, Oromia, and Sothern Nations Nationalities and Peoples Region (SNNPRs) were categorized under **larger central regions**; Afar, Somali, Benishangul, and Gambella were under **Small peripherals**, while **Metropolis** include Harari, Dire Dawa, and Addis Ababa regions.	0. Metropolis 1. Large centrals 2. Small peripherals
Electricity access	Household who had access to electricity at the time of survey	0. No 1. Yes
Access to water	Water available on-premises plus accessed in less than 30 min inround trip (**Basic**) vs requires greater than 30 min to access (**limited).**	0. Basic 1. Limited
Place of cooking	The place where the households cooked foods at the time of the survey	1. In the house 2. In a separate building 3. Outdoors
Place of residence	The place where the household heads residing at a time of survey	0. Urban 1. Rural

were included. Most of the variables were taken directly as they were in the EDHS data set. However, individual variables such as wealth index, age of the household,[4] educational status, household size,[20] and place of cooking food were reclassified. A wealth index was created using principal component analysis. The questionnaires in EDHS were asked "what the households own based on an extensive list of assets and other housing characteristics that reflect their economic status" and households were given scores based on the number and kinds of consumer goods they own, ranging from a television to a bicycle or car, in addition to housing characteristics such as a source of drinking water, toilet facilities, and flooring materials. The categories of all extracted explanatory variables were shown in Table 1.

Individual data sets from EDHS were used to generate community-level factors such as media exposure, community-level poverty, and education. The generated variables were further categorized based on the mean values. The measurement of community variables were as follows: Community media exposure was defined as the proportion of household heads who had exposure to the media within the cluster and it was assessed by the proportion of household heads who had at least been exposed to 1 media.[21] The aggregate of individual households with mass media exposure might show the overall mass media exposure of the cluster. It was categorized as high if more than half of the households (50%) in the cluster had exposure to the media, or low if less otherwise. It was coded as

"0" for low-level media coverage and "1" for high-level media coverage at the community level.[22,23]

Community-level education was defined as the proportion of household heads who attended a minimum of primary level of education within the cluster. The sum of individual household heads with a minimum of primary level of education could represent the overall educational attainment of the cluster. It was categorized as high if the clusters had more than or equal to 50% minimum primary education level, and low otherwise. It was coded as "0" for low-level education coverage and "1" for high-level education coverage at the community level.

Community-level poverty was defined as the proportion of households in the cluster that was poor or poorest. The aggregate of individual households with the poorest or poor wealth index can reveal the cluster's overall poverty. It was categorized as high if the clusters had more than or equal to 50% of the poorest or poor households, or low otherwise. It was categorized as "0" to indicate low poverty and as "1" to indicate high poverty at the community level.

The region of Ethiopia was divided into 3 geopolitical regions (larger central, small peripherals, or metropolis). These classification was based on previous literature.[24,25] Tigray, Amhara, Oromia, and the Sothern Nations Nationalities and Peoples Region (SNNPRs were among the larger central regions). Afar, Somalia, Benishangul, and Gambella were included small peripherals, whereas Harari, Dire Dawa, and Addis Ababa were metropolitan areas.

Data analysis

EDHS data had been extracted, coded, and analyzed using Stata version 14 software. Both descriptive and analytical statistics were computed. Due to the hierarchical and clustering nature of the data, a mixed effect multilevel logistic regression (household and community level) was introduced. Because solid fuel consumption was expected to differ between clusters, a cluster-level random intercept was introduced in the mixed logit model. The intra-class coefficient was used to measure the proportion of observed variation in the outcome that attributed to the clustering effect.[26,27] Fixed effects were utilized to identify the relationship between solid fuel use and explanatory variables at the individual and community levels. Variables with a *P*-value less than .25 in the bivariate analysis were candidates for the adjusted model.[28] Adjusted odds ratio with a 95% confidence interval and *P*-value $<.05$ was considered to have a significant association with the outcome. Deviance was used to check the model's goodness of fit. Multicollinearity was checked and the VIF value for all variables was less than 10.

Model building

Four models were introduced in the multilevel analysis. The first was a null model (Model 1) that was designed to check the variability in the use of solid fuels and only contains the outcome variables. The second (model 2) and third (model 3) were hierarchical models that included factors at the individual and community levels, respectively. In the fourth model (Model 4), both the community and individual variables associated with the use of solid fuel were fitted simultaneously. Model comparison was done using the deviance test and the lowest deviance was chosen as the best-fitting model.

Random effects (a measure of variation)

Variation was estimated by the median odds ratio (MOR), the intra-cluster correlation coefficient (ICC), and the proportional change in variance (PCV). MOR is defined as the central value of the odds ratio between the highest and the lowest solid fuel user when randomly selecting 2 clusters and was calculated using the formula.[22] The PCV reveals the variation in solid fuel use in communities that is explained by factors at the individual and community level factors; it was determined using the formula.[22] The ICC indicates the variation in the use of solid fuel between clusters, which was calculated both manually and using the Stata command.[22]

The calculation for median odds ratio (MOR), ICC, and Proportional Change in Variance (PCV) is as follows;

$\text{MOR} = \exp.[\sqrt{(2 \times \text{VA})} \times 0.6745]$, or $MOR = e^{0.95\sqrt{VA}}$ where; VA is the area level variance.[22,29,30]

The PCV reveals the variation in solid fuel use among households explained by factors. The PCV is calculated as; $PCV = \frac{Vnull - VA}{V\,null} * 100\%$ where; Vnull = variance of the initial model, and VA = variance of the model with more terms.

The ICC which reveals the variation of using solid fuel between clusters is calculated as; $ICC = \frac{VA}{VA + 3.29} * 100\%$, where; VA = area/cluster level variance.[22,29,30]

Ethics approval

The authors followed DHS standards and procedures to obtain publicly available data from http://www.measuredhs.com. We were granted permission from CSA through its data manager by using the online form.

Results

Socio-demographic characteristics of the household heads

There were 16 650 weighted households involved in this study. The mean age of the household head was 44.2 years with (SD ± 0.13). Males were the majority of the household heads (12 425) (74.63%). According to these data, the majority of survey participants 13 266 (79.68%) were rural residents. Household heads without formal education accounted for 9131 (54.84%), primary school accounted for 5027 (30.19 %), and secondary and above accounted for 2491 (14.97 %).

In terms of wealth index, poor households accounted for 6406 (38.47%), households with middle income accounted for 3121 (18.75%), and rich households accounted for 7123 (42.78%). Around half of the household heads, 7881 (47.80%) cooked in separate buildings. The majority of the respondents, 12 379 (74.35%), did not have access to electricity and more than half of the respondents, 8784 (52.76%), did not have media exposure. In this study, 892 (5.36%) households lived in the Metropolis region, 14 875 (89.34%) in the Large Centrals, and 883 (5.30%) in the Small Peripherals region. The socio-demographic characteristics of the head of the household are summarized in the table below (Table 2).

Results of the mixed effect model parameter

Random-effects and model comparisons. As indicated in Table 2, the ICC in the null model was 0.81, indicating that about 81% of the variations in the use of solid fuel between households were attributed to the difference at the cluster level, but the rest 19% were attributed to individual household factors. The MOR value was 33.79, in the null model, which showed the median odds between the lowest and the highest solid fuel user in the clusters. Furthermore, PCV in the final model was 90%, indicating that the variation in solid fuel use among study households was explained by factors at both the individual and community levels simultaneously. The fourth model has the lowest deviation (3528) and was taken as the best-fitted model (Table 2).

Mixed-effect analysis of factors associated with solid fuel use in Ethiopia. All variables that have a *P*-value <.25 in the bivariate analysis were selected for multivariate analysis. In the second model, individual-level variables including the age of the household head, the educational attainment of the household head, the marital status of the household head, the size of the household, the household wealth index, electricity access, water access, and the place of cooking food had a significant association with solid fuel use, as well as community-level factors such as residence, media exposure, and community poverty was significantly associated in the third model. Based on the final model (model 4), variables such as the age of the head of household, educational attainment of the head of household, marital status of the head of household, household family size, household wealth index, electricity access, place of cooking food, residence, and region were significantly associated with solid fuel use.

As the household heads' age increases solid fuel use is less likely than for younger household heads, where 78% for younger and 84% for older with (AOR = 0.22, 95% CI = 0.08, 0.62) and (AOR = 0.16, 95% CI = 0.05-0.48] respectively. The household heads without formal education 3.82 (AOR = 3.82, 95% CI = 2.82, 5.17) and who attended primary education 3.09 (AOR = 3.09, 95% CI = 2.44, 3.91) times higher odds of solid fuel use compared to household heads who attend secondary and above educational level respectively.

Regarding the marital status of the head of household, those married and divorced were 1.48 (95% CI = 1.07, 2.07) and 1.85 (95% CI = 1.19, 2.87) times higher in solid fuel than those never married, respectively. Household heads with family size greater than 5 had 0.69 times lower to use solid fuel type than those households that had less than equal to 2 family sizes (AOR = 0.69, 95% CI = 0.52-0.93).

In addition, households with access to electricity had 71% less solid fuel use than their counterparts (AOR = 0.29, 95% CI = 0.16, 0.51). Solid fuel use was less likely in middle and upper-income households, which was 78% (AOR = 0.22, 95% CI = 0.09, 0.53) and 92% (AOR = 0.08, 95% CI = 0.04, 0.18), respectively. Regarding the place of cooking, households cooked their food in a separate building and outdoors were 2.90 (95% CI = 2.33, 3.60) and 4.13 (95% CI = 2.96, 5.76) times higher in the use of solid fuel than those cooked their food inside the house, respectively.

The likely hood of using solid fuel was 0.18 (95% CI = 0.09, 0.38) times lower in urban household heads than in their counterparts. Household heads who live in the large central and small peripheral regions of Ethiopia were 7.06 (95% CI = 4.31, 11.55) and 14.44 (95% CI = 6.12, 34.04) times higher in solid fuel use than in the metropolis region, respectively. The factors associated with the use of solid fuels are summarized in the table below (Table 3).

Discussion

In Ethiopia, the most common solid fuels were coal, lignite, charcoal, wood, straw, shrub, grass, crops, and animal dung. Determining the magnitude and determinants of solid fuel use at the national level was highly suggested. In this study, the ICC in the null model showed that about 81% of the variations in the use of solid fuel were attributed to the difference at the cluster level. The possible reason might be that clusters may vary in their social, cultural, and economical value. For example, those clusters which have awareness about the impact of solid fuel use could choose the modern fuel types. In this study, the MOR value was higher, indicating a significant difference between the cluster's lowest and greatest solid fuel users. This finding is supported by solid fuel use evidence from Ethiopia,[31] where the likelihood of using solid fuel was varied nearly 2-fold and 9-fold among communities and districts, respectively. A MOR value larger than 1 indicates significant differences between clusters.[31] The PCV in this study revealed that there was variation in solid fuel usage among households due to individual and community-level characteristics.

In this study, the prevalence of solid fuel use among households in Ethiopia was 94.03% (95% CI = 93.66, 94.37). This finding was higher than studies done in sub-Saharan Africa (68%),[32] Nigeria 63.3%,[33] 65.1% in China,[34] and 71% in Africa,[35] where unclean fuels are still the main source of fuel for cooking. The disparity may be attributable to differences in the study setting, sample size, and the socioeconomic state of the countries. This finding should come as no surprise given that

Table 2. Socio-demographic characteristics of household heads in Ethiopia, 2021: Data from the Ethiopian Demographic and Health Survey 2016 (n = 16 650).

VARIABLES	CATEGORIES	SOLID FUEL USE OF HH, N (%)		TOTAL WEIGHTED FREQUENCY (%)
		YES N = 15 655 (94.03%)	NO N = 995 (5.97%)	
Age of HH head	<18	148 (96.83)	5 (3.17)	153 (0.92)
	18-30	3468 (92.56)	279 (7.44)	3747 (22.50)
	31-45	5409 (94.32)	325 (5.68)	5734 (34.44)
	46-65	4690 (94.18)	289 (5.82)	4979 (29.91)
	>66	1939 (95.29)	96 (4.71)	2035 (12.22)
Sex of the head	Male	11 774 (94.76)	651 (5.24)	12 425 (74.63)
	Female	3880 (91.87)	344 (8.13)	4224 (25.37)
Educational status of HH head	No formal education	8970 (98.24)	161 (1.76)	9131 (54.84)
	Primary school	4789 (95.27)	238 (4.73)	5027 (30.19)
	Secondary and above	1895 (76.07)	596 (23.93)	2491 (14.97)
Marital status of the head	Never married	619 (78.02)	175 (21.98)	794 (4.77)
	Married	12 093 (95.27)	600 (4.73)	12 693 (76.28)
	Widowed	1806 (92.46)	147 (7.54)	1953 (11.74)
	Divorced	1127 (93.96)	72 (6.04)	1199 (7.21)
Household size	<2	2727 (89.59)	317 (10.41)	3044 (18.28)
	3-4	4955 (93.75)	330 (6.25)	5285 (31.75)
	>5	7973 (95.83)	347 (4.17)	8320 (49.97)
Wealth index	Poor	6397 (99.86)	9 (0.14)	6406 (38.47)
	Middle	3104 (99.44)	17 (0.56)	3121 (18.75)
	Rich	6155 (86.41)	968 (13.59)	7123 (42.78)
Electricity access	Yes	3344 (78.31)	926 (21.69)	4270 (25.65)
	No	12 311 (99.45)	68 (0.55)	12 379 (74.35)
Water access	Basic	8280 (89.90)	929 (10.10)	9209 (55.31)
	Limited	7376 (99.13)	64 (0.87)	7440 (44.69)
Place of cooking food	In the house	6121 (92.14)	522 (7.86)	6643 (40.29)
	In separate building	7481 (94.93)	400 (5.07)	7881 (47.80)
	Outdoor	1892 (3.68)	72 (96.32)	1964 (11.91)
Community level variables				
Place of residence	Urban	2484 (73.41)	899 (26.59)	3383 (20.32)
	Rural	13 172 (99.29)	94 (0.71)	13 266 (79.68)
Region	Metropolis	411 (46.04)	481 (53.96)	892 (5.36)
	Large centrals	14 373 (96.62)	502 (3.38)	14 875 (89.34)
	Small peripherals	872 (98.73)	11 (1.27)	883 (5.30)
Media exposure	Yes	6913 (87.89)	953 (12.11)	7866 (47.24)
	No	8742 (99.53)	42 (0.47)	8784 (52.76)
Community educational level	High	6873 (87.87)	949 (12.13)	7822 (46.98)
	Low	8782 (99.48)	46 (0.52)	8828 (53.02)
Community level of poverty	High	8013 (99.62)	31 (0.38)	8044 (48.31)
	Low	7643 (88.80)	963 (11.20)	8606 (51.69)

Abbreviation: HH, household.

Table 3. Factors associated with solid fuel use among households in Ethiopia, 2021: Data from 2016 EDHS (n = 16 650).

VARIABLES	CATEGORIES	NULL MODEL	MODEL 1	MODEL 2	MODEL 3
			AOR [95% CI]	AOR [95% CI]	AOR [95% CI]
Age of HH head	<18		Ref		Ref
	18-30		0.21 [0.08-0.60]**		0.22 [0.08-0.62]**
	31-45		0.20 [0.07-0.57]**		0.23 [0.07-0.64]**
	46-65		0.14 [0.15-0.47]***		0.16 [0.06-0.47]**
	>66		0.12 [0.41-0.37]***		0.16 [0.05-0.48]**
Sex of HH head	Male		Ref		Ref
	Female		1.15 [0.88-1.49]		1.24 [0.96-1.67]
Educational status of HH head	No education		4.55 [3.36-6.15]***		3.82 [2.82-5.17]***
	Primary education		3.33 [2.62-4.21]***		3.09 [2.44-3.91]***
	Secondary and above		Ref		Ref
Marital status	Never married		Ref		Ref
	Married		1.54 [1.12-2.14]*		1.48 [1.07-2.07]*
	Widowed		0.74 [0.47-1.15]		0.76 [0.48-1.19]
	Divorced		1.86 [1.19-2.89]**		1.85 [1.19-2.87]**
Household size	<2		Ref		Ref
	3-4		1.01 [0.78-1.30]		1.02 [0.79-1.32]
	>5		0.74 [0.56-0.99]*		0.69 [0.52-0.93]*
Wealth index	Poor		Ref		Ref
	Middle		0.19 [0.08-0.45]***		0.22 [0.09-0.53]**
	Rich		0.05 [0.02-0.16]***		0.08 [0.04-0.18]***
Electricity access	No		Ref		Ref
	Yes		0.05 [0.03-0.07]***		0.29 [0.16-0.51]***
Water access	Basic		Ref		Ref
	Limited		1.46 [1.00-2.13]*		1.08 [0.75-1.58]
Place of cooking	In the house		Ref		Ref
	In separate building		3.20 [2.57-3.97]***		2.90 [2.33-3.60]***
	Outdoors		4.08 [2.92-5.67]***		4.13 [2.96-5.76]***
Residence	Rural			Ref	Ref
	Urban			0.05 [0.03-0.11]***	0.18 [0.09-0.38]***
Region	Metropolis			Ref	Ref
	Large central			7.70 [4.71-12.58]***	7.06 [4.31-11.55]***
	Small peripherals			21.16 [9.16-48.87]***	14.44 [6.12-34.04]***
Com. Media	Low			Ref	Ref
	High			0.71 [0.36-1.40]	1.10 [0.56-2.19]

(Continued)

Table 3. (Continued)

VARIABLES	CATEGORIES	NULL MODEL	MODEL 1	MODEL 2	MODEL 3
			AOR [95% CI]	AOR [95% CI]	AOR [95% CI]
Com. Poverty	Low			Ref	Ref
	High			2.71 [1.38-5.31]**	1.20 [0.60-2.39]
Com. Education	Low			Ref	Ref
	High			0.40 [0.22-0.73]	0.66 [0.36-1.22]
Random effect					
	VA	13.73	2.73	1.56	1.44
	ICC	0.81	0.45	0.32	0.31
	MOR	33.79	4.81	3.27	3.13
	PCV	Ref	0.80	0.89	0.90
Model comparison					
	Deviance	4536	3698	4020	3528

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; Com. Education, community educational status; Com. Media, community media use; Com. Poverty, community poverty; HH, Household; ICC, inter-cluster correlation coefficient; MOR, median odds ratio; PCV, a proportional change in variance; Ref, Reference group. *P-value <.05. **P-value <.01. ***P-value <.001.

most of Ethiopia's population lives in rural areas, where wood and agricultural wastes are the primary sources of energy.[36] Fuelwood demand is fast increasing while availability is decreasing. Scarcity of wood leads to intensive use of agricultural residues and animal dung for cooking, which could otherwise have been utilized to improve the nutrient status and texture of the soil.[36] In addition, indoor air pollution caused by the use of solid fuels causes lung and eye diseases, and the health expenses are larger than the costs of alternative fuels.[37] The reason for this could be that solid fuels produce microscopic particulate debris that can accumulate in the lungs.[16] Individuals' mental health may be impacted by the usage of solid fuels because it takes a longer time to acquire fuel and cook.[38] Therefore, the Ethiopian government will be able to plan a long-term clean energy policy and legal measures for the development of ecologically friendly energy sources, as well as the equitable distribution of clean fuels throughout the country.

In this study, older household heads were less likely to use solid fuels. This finding was contradicted with previous studies conducted in Ethiopia,[4] Nigeria,[33] Southern Africa,[39] and Uganda[40]; a rise in the age of the household head is more likely to favor solid fuels over clean fuels. The main reason for this might be that older household heads are more eager to retain norms and traditions, which encourages the use of solid fuels. However, in our scenario, those older-age household heads may perceive health risks and the cost of health care as a result of solid fuel consumption. For example, the risk of asthma and eye problems increases considerably with age because air pollution accumulates over time and reaches a threshold level in later years.[37]

In addition, the educational level of the household heads was significantly associated with the use of solid fuel. Similar findings were discovered in China,[34] India,[41] Guatemala,[42] Ethiopia,[4] and Nigeria,[33] thus implying that a lower level of education of the household head is more likely to choice of solid fuels. A possible explanation is that lower levels of education reduce household income, awareness of fuel qualities, and preference for new clean fuels. A highly educated household, on the other hand, may lack time to collect traditional fuel types due to their involvement in other activities.[43] Furthermore, it is difficult for household heads with low educational levels to gain knowledge regarding health problems due to solid fuel use. As well as, illiterate households would be unfamiliar with the cooking technique associated with modern fuels. Our survey also revealed that about 98.24% of Ethiopian household heads have no formal education. This suggested that Ethiopians have limited understanding, views, and attitudes about health-friendly cooking technologies. Increasing educational opportunities, as well as clean fuels promotion through the media, is critical to raising people's awareness. Having information allows one to take preventive measures, such as installing home air purifiers to limit the negative effects of solid fuels. Along with other initiatives, programs aimed at raising awareness of the health risks associated with solid fuels are also warranted.

The likelihood of using solid fuel was higher among household heads who get married and divorced and a similar finding was recorded in Uganda,[40] where married and divorced household heads are more likely to restrict their use of modern cooking fuels. The reason behind this might be that those household heads may have children, and hence they have access to solid

fuels through its gathering by their children. Another reason could be that such household heads may have a large family size, necessitating the usage of a significant amount of solid fuels to feed a large number of people at the same time.

The likelihood of using solid fuel was lower when the wealth index increased. This finding is consistent with studies done in Ethiopia,[4,44] India,[41,45] China,[46] Guatemala,[29] Nigeria,[33] and Uganda,[40] which have found that households changed from using "solid fuel" to "non-solid fuels" as household income increases. A better household income increases the ability to buy clean and expensive fuels. It also leads to a higher standard of living, which reduces the risk of diseases associated with solid fuel use.[37] As a result, assisting the disadvantaged people in the economy will help to increase clean fuel usage in Ethiopia. The government recently implemented initiatives to introduce clean cooking to households by increasing access to improved stoves and subsidizing fuel for poor households.

In this survey, when an increase in the household size less likely to use solid fuels. The finding is consistent with research done in China[41] and differs from findings in Nigeria,[42] Guatemala,[42] and India,[45] the bigger the number of people in the household, the greater the likelihood of utilizing solid fuels. The discrepancy between countries could be the difference in the sample size. In our survey, households with big family sizes may need a fast and clean fuel type to cook for many people at a time. In addition, many people may require a large amount of solid fuel in the aggregate, which may oblige them to prefer clean fuels even if they are costly. Theoretically, larger household sizes may imply more labor input (children's labor), which may then be used to freely harvest solid fuels from public fields. Households with big family size, on the other hand, will have a better opportunity to establish a business and educate their children to use clean fuels rather than wasting time in collecting these solid fuels.

In this finding, the place of cooking was positively and significantly associated with the use of solid fuels. This finding is supported by a study done in Nigeria,[33] which was found that households that used outdoor cooking and a separate cooking building were more likely to use solid fuels. The reason might be that outdoor and separate cooking areas are designed in a way that the smoke does not cause pollution for the main dwelling unit. Furthermore, households may feel free that outdoor cooking is less risky than inside cooking in terms of health problems.[47] Another reason could be that most of the households in this survey lived in rural locations and they could use open fires to cook their food; this does not encourage the use of modern clean fuels. Cooking foods within the residence unit will induce respiratory tract infections, especially in children under the age of 5, since they breathe significant amounts of contaminated air to their body size due to increased minute ventilation as they are more active.[48] The solid fuel smoke also contributed to sleep disturbances, which were especially prevalent in an aging population.[49] People who live in houses with a separate kitchen have a significantly lower risk of tuberculosis than people who live in households without a separate kitchen.[50] The concentration of particulate matter was found to be lower in households that cooked in a separate kitchen or had doors and windows open after cooking.[51] However, even if they do not use clean fuels, having a separate cooking place is beneficial to health.

Access to electricity in cities was significantly associated with the use of solid fuel, which is consistent with studies in Guatemala,[42] developing countries,[35] Peru,[52] and Southern Africa,[39] where low access to electricity is found to be associated with lower use of solid fuels. However, the study conducted in China was not significant.[34] These findings support our anticipation that infrastructure improvements will make it easier for households to get clean fuels. In households, access to electricity depends on the willingness of the landlord (renter). Such circumstances prove that availability does not always guarantee accessibility and its frequent interruption in the city is also another barrier. Electricity does not emit any pollution, but the main difficulty is accessibility.[53] Households do not return to solid fuels as electricity prices rise, but they do try to reduce the budget burden of electricity by using solid fuels to meet the rest of their demands.[54] In this study, the prevalence of electricity, liquefied petroleum gas (LPG), natural gas, biogas were 47 (3.35%), 24 (43.64%), 2 (6.06%), and 2 (4.17%) respectively. This demonstrated that electricity was not widely available at the national level.

According to this survey, living in an urban location reduces the likelihood of using solid fuels. The association between place of residence and less use of solid fuel in this study is not surprising, given that access to clean fuels varies significantly in coverage between urban and rural inhabitants in Ethiopia. This finding is supported by research done in less developing countries,[35] Peru,[52] and Uganda,[40] which shows that urban households are more likely to use modern fuel. This was also confirmed by the fact that non-agricultural households choose to use clean fuels since they did not easily access solid fuels.[45] In addition, urban residents may be more aware of the health and environmental risks of burning solid fuels as a result of exposure to education and media than rural residents. The use of solid fuel as the main cooking fuel will reduce urban air quality. In rural areas, the wood need is met via collecting, but urban residents meet their demand by purchasing.[36] The majority of rural Ethiopians rely on the free collection of woody biomass, crop leftovers, and animal excrement. However, today's overuse of wood creates an overload on a country's plants.

A household head who lived in the large central and small peripheral regions of Ethiopia was highly significantly associated with solid fuels. Our finding was expected and the possible explanation is that these regions are province areas, with a large proportion of their population living in rural areas compared to metropolitan regions. As a result, they did not have

sufficient access to clean fuels, such as electricity, and their only option was to use solid fuels, which could be found nearby at a lower cost. The findings are reinforced by China[34] and Peru,[52] where the magnitude of solid fuel consumption is higher in non-capital regions than in capital regions.

Limitation

The limitation of this study was the use of EDHS (secondary) data for this study, and thus all variables that influence solid fuel use were not included, such as the price of fuel, the employment status of the head of household, the taste of preference, type of cooked food, the cooking frequency, and the like due to the unavailability in the dataset, which may have effects on the choice of cooking fuel type. Therefore, future investigators should include these factors. In addition, this study had limitation on addressing a recall bias and transient or multiple fuel users of participants duto secondary nature of EDHS data.

Strength

The study also has certain strengths. First, the data was from the EDHS, which is a national-level, well-representative, and high-quality sample. Second, to the best of our knowledge, this is the first national investigation on this topic in Ethiopian contexts; third, this study has examined the effect of community poverty and education on solid fuel consumption. In conclusion, we evaluated the impacts of communities or clusters on solid fuel consumption using multilevel logistic regression models rather than simple regression models.

Conclusions

The use of solid fuels remains high in Ethiopia due to different influencing factors. In this study, the age of the household head, educational status of household head, marital status of household head, wealth index of the household, household size, place of cooking, electricity access, residence, and region were significantly associated with solid fuel use.

Recommendations

The Ethiopian government and other responsible organizations should work more to increase the accessibility of rural households to clean energy sources through an electricity supply and raise awareness regarding the consequence of using polluting solid fuels. Policymakers should focus on creating a solutions by promoting widespread education and eradicating poverty by improving household income levels to encourage the shift to cleaner energy sources.

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Author Contributions

All stated authors ME, DG, NT, FM, MG, and MH are involved in the conception, design, acquisition of data, analysis and interpretation and drafting of the manuscript, and approval of the final version of the manuscript.

Data Availability Statement

All relevant data are within the manuscript, and data are available publically access from the open databases. It can be accessed from the following website: http://www.measuredhs.com.

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REFERENCES

1. Chen C, Liu GG, Sun Y, et al. Association between household fuel use and sleep quality in the oldest-old: evidence from a propensity-score matched case-control study in Hainan, China. *Environ Res*. 2020;191:110229.
2. Debbi S, Elisa P, Nigel B, Dan P, Eva R. Factors influencing household uptake of improved solid fuel stoves in low- and middle-income countries: a qualitative systematic review. *Int J Environ Res Public Health*. 2014;11:8228-8250.
3. World Health Organization. *WHO Guidelines for Indoor Air Quality: Household Fuel Combustion*. World Health Organization; 2014.
4. Truneh GB. *Factors Influencing Household Cooking Energy Choice and Transition: Empirical Evidence From Mekelle City, Ethiopia. Master's Programme in Urban Management and Development*. International Institute of Urban Management Erasmus University; 2014.
5. Bonjour S, Adair-Rohani H, Wolf J, et al. Solid fuel use for household cooking: country and regional estimates for 1980-2010. *Environ Health Perspect*. 2013;121:784-790.
6. Vaccari M, Vitali F, Mazzù A. Improved cookstove as an appropriate technology for the Logone Valley (Chad – Cameroon): analysis of fuel and cost savings. *Renew Energy*. 2012;47:45-54.
7. Macro O. *Ethiopia Demographic and Health Survey 2005*. Central Statistical Agency; 2006.
8. Desalegn B, Suleiman H, Asfaw A. Household fuel use and acute respiratory infections among younger children: an exposure assessment in Shebedino Wereda, southern Ethiopia. *Afr J Health Sci*. 2011;18:31-36.
9. World Health Organization. *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*. World Health Organization; 2009.
10. Lam NL, Smith KR, Gauthier A, Bates MN. Kerosene: a review of household uses and their hazards in low- and middle-income countries. *J Toxicol Environ Health B*. 2012;15:396-432.
11. Desai MA, Mehta S, Smith KR; World Health Organization. *Indoor Smoke From Solid Fuels: Assessing the Environmental Burden of Disease at National and Local Levels*. World Health Organization; 2004.
12. World Health Organization. *The World Health Report: Primary Health Care Now More Than Ever*. World Health Organization; 2008.
13. Demelash H, Motbainor A, Nigatu D, Gashaw K, Melese A. Risk factors for low birth weight in Bale zone hospitals, South-East Ethiopia: a case-control study. *BMC Pregnancy Childbirth*. 2015;15:264.
14. Mitchell EJS. *Emissions From Residential Solid Fuel Combustion and Implications for Air Quality and Climate Change*. University of Leeds; 2017.
15. Mekonnen A, Köhlin G. Determinants of household fuel choice in major cities in Ethiopia. 2009. https://gupea.ub.gu.se/handle/2077/21490.
16. Admasie A, Kumie A, Worku A. Children under five from houses of unclean fuel sources and poorly ventilated houses have higher odds of suffering from acute respiratory infection in Wolaita-Sodo, southern Ethiopia: a case-control study. *J Environ Public Health*. 2018;2018:9320603.
17. Rehfuess E; World Health Organization. *Fuel for Life: Household Energy and Health*. World Health Organization; 2006.
18. CSA, ICF. *2016 Ethiopia Demographic and Health Survey Key Findings*. CSA and ICF; 2016.
19. Ethiopia FDR. *Ethiopia Demographic and Health Survey 2016*. CSA; 2016.

20. Tirore LL, Mulugeta A, Belachew AB, et al. Factors associated with anaemia among women of reproductive age in Ethiopia: multilevel ordinal logistic regression analysis. *Matern Child Nutr*. 2021;17:e13063.
21. Sahiledengle B. Prevalence and associated factors of safe and improved infant and young children stool disposal in Ethiopia: evidence from demographic and health survey. *BMC Public Health*. 2019;19:1-13.
22. Liyew AM, Teshale AB. Individual and community level factors associated with anemia among lactating mothers in Ethiopia using data from Ethiopian demographic and health survey, 2016; a multilevel analysis. *BMC Public Health*. 2020;20:775.
23. Teshale AB, Tesema GA. Prevalence and associated factors of delayed first antenatal care booking among reproductive age women in Ethiopia; a multilevel analysis of EDHS 2016 data. *PLoS One*. 2020;15:e0235538.
24. Ahmed KY, Page A, Arora A, Ogbo FA. Trends and determinants of early initiation of breastfeeding and exclusive breastfeeding in Ethiopia from 2000 to 2016. *Int Breastfeed J*. 2019;14:40.
25. Abrha S, Shiferaw S, Ahmed KY. Overweight and obesity and its socio-demographic correlates among urban Ethiopian women: evidence from the 2011 EDHS. *BMC Public Health*. 2016;16:636.
26. Austin PC, Merlo J. Intermediate and advanced topics in multilevel logistic regression analysis. *Stat Med*. 2017;36:3257-3277.
27. Nalborczyk L. Three methods for computing the intra-class correlation in multilevel logistic regression. *Barely Significant*, October 8, 2017.
28. Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. *Source Code Biol Med*. 2008;3:17-18.
29. Merlo J, Chaix B, Yang M, Lynch J, Råstam L. A brief conceptual tutorial of multilevel analysis in social epidemiology: linking the statistical concept of clustering to the idea of contextual phenomenon. *J Epidemiol Community Health*. 2005;59:443-449.
30. Merlo J, Chaix B, Yang M, Lynch J, Rastam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: interpreting neighbourhood differences and the effect of neighbourhood characteristics on individual health. *J Epidemiol Community Health*. 2005;59:1022-1029.
31. Rehfuess EA, Briggs DJ, Joffe M, Best N. Bayesian modelling of household solid fuel use: insights towards designing effective interventions to promote fuel switching in Africa. *Environ Res*. 2010;110:725-732.
32. Amadu I, Seidu A-A, Duku E, et al. The joint effect of maternal marital status and type of household cooking fuel on child nutritional status in Sub-Saharan Africa: analysis of cross-sectional surveys on children from 31 countries. *Nutrients*. 2021;13:1541.
33. Baiyegunhi LJ, Hassan MB. Rural household fuel energy transition: evidence from Giwa LGA Kaduna State, Nigeria. *Energy Sustain Dev*. 2014;20:30-35.
34. Peng W, Hisham Z, Pan J. Household level fuel switching in rural Hubei. *Energy Sustain Dev*. 2010;14:238-244.
35. McLean EV, Bagchi-Sen S, Atkinson JD, Ravenscroft J, Hewner S, Schindel A. Country-level analysis of household fuel transitions. *World Dev*. 2019;114:267-280.
36. Benti NE, Gurmesa GS, Argaw T, et al. The current status, challenges and prospects of using biomass energy in Ethiopia. *Biotechnol Biofuels*. 2021;14:209-224.
37. Pant KP. Cheaper fuel and higher health costs among the poor in rural Nepal. *Ambio*. 2012;41:271-283.
38. Liu Y, Chen X, Yan Z. Depression in the house: the effects of household air pollution from solid fuel use among the middle-aged and older population in China. *Sci Total Environ*. 2020;703:134706.
39. Makonese T, Ifegbesan AP, Rampedi IT. Household cooking fuel use patterns and determinants across southern Africa: evidence from the demographic and health survey data. *Energy Environ*. 2018;29:29-48.
40. Katutsi V, Dickson T, Migisha AG. Drivers of fuel choice for cooking among Uganda's households. *Open J Energy Efficiency*. 2020;9:111-129.
41. Farsi M, Filippini M, Pachauri S. Fuel choices in urban Indian households. *Environ Dev Econ*. 2007;12:757-774.
42. Heltberg R. Factors determining household fuel choice in Guatemala. *Environ Dev Econ*. 2005;10:337-361.
43. Pundo MO, Fraser GC. Multinomial logit analysis of household cooking fuel choice in rural Kenya: the case of Kisumu district. *Agrekon*. 2006;45:24-37.
44. Mekonnen A, Köhlin G. Biomass fuel consumption and dung use as manure: evidence from rural households in the Amhara region of Ethiopia. Environment for Development Discussion Paper (08-17), Resources for the Future (RFF). 2008.
45. Pandey VL, Chaubal A. Comprehending household cooking energy choice in rural India. *Biomass Bioenergy*. 2011;35:4724-4731.
46. Hou B, Liao H, Huang J. Household cooking fuel choice and economic poverty: evidence from a nationwide survey in China. *Energy Build*. 2018;166:319-329.
47. Amegah AK, Jaakkola JJ, Quansah R, Norgbe GK, Dzodzomenyo M. Cooking fuel choices and garbage burning practices as determinants of birth weight: a cross-sectional study in Accra, Ghana. *Environ Health*. 2012;11:78.
48. Nandasena S, Wickremasinghe AR, Sathiakumar N. Indoor air pollution and respiratory health of children in the developing world. *World J Clin Pediatr*. 2013;2:6-15.
49. Yu H, Luo J, Chen K, Pollitt KJG, Liew Z. Solid fuels use for cooking and sleep health in adults aged 45 years and older in China. *Sci Rep*. 2021;11:13304.
50. Mishra VK, Retherford RD, Smith KR. Biomass cooking fuels and prevalence of tuberculosis in India. *Int J Infect Dis*. 1999;3:119-129.
51. Dasgupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D. Who suffers from indoor air pollution? Evidence from Bangladesh. *Health Policy Plan*. 2006;21:444-458.
52. McLean EV, Bagchi-Sen S, Atkinson JD, Schindel A. Household dependence on solid cooking fuels in Peru: an analysis of environmental and socioeconomic conditions. *Glob Environ Change*. 2019;58:101961.
53. Ellegård A. Cooking fuel smoke and respiratory symptoms among women in low-income areas in Maputo. *Environ Health Perspect*. 1996;104:980-985.
54. Alem Y, Beyene AD, Kohlin G, Mekonnen A. Household fuel choice in urban Ethiopia: a random effects multinomial logit analysis. Discussion Papers dp-13-12-efd, Resources For the Future. 2013.