


Is Indoor Air Pollution From Different Fuel Types Associated With the Anemia Status of Pregnant Women in Ethiopia?

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Abstract

Background: Indoor air pollution from different fuel types has been linked with different adverse pregnancy outcomes. The study aimed to assess the link between indoor air pollution from different fuel types and anemia during pregnancy in Ethiopia. **Method:** We have used the secondary data from the 2016 Ethiopian Demographic and Health Survey data. The anemia status of the pregnant women was the dichotomous outcome variable and the type of fuel used in the house was classified as high, medium, and low polluting fuels. Logistic regression was employed to determine the association between the exposure and outcome variables. Adjusted Odds Ratio was calculated at 95% Confidence Interval. **Result:** The proportion of anemia in the low, medium, and high polluting fuel type users was 13.6%, 46%, 40.9% respectively. In the multivariable logistic regression analysis, the use of either kerosene or charcoal fuel types (AOR 4.6; 95% CI: 1.41-18.35) and being in the third trimester (AOR 1.72; 95% CI: 1.12-2.64) were significant factors associated with the anemia status of the pregnant women in Ethiopia. **Conclusion:** According to our findings, the application of either kerosene or charcoal was associated with the anemia status during pregnancy in Ethiopia. An urgent intervention is needed to reduce the indoor air pollution that is associated with adverse pregnancy outcomes such as anemia.

Keywords

anemia, demographic and health survey, fuel type, pregnancy, Ethiopia

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Introduction

Anemia is an adverse health condition that occurs when the number of red blood cells (and consequently their oxygen-carrying capacity) is inadequate to meet the physiologic needs of the body.¹ It is one of the adverse health outcomes, which affects 32.4 million (38.2%) pregnant women around the globe.^{2,3} According to the World Health Organization (WHO) assessment more than 50% of all women living in developing nations are anemic, in contrast with 18% in economically developed nations. Africa and Asia are facing most of the adverse consequence of a problem with 60 and 52% of their women are estimated to be anemic respectively.⁴ The situation in Ethiopia in terms of anemia is more severe than in other developing countries where more than 62.7% of pregnant and 52.3% non-pregnant women are affected by the problem.⁵ As in most developing nations, anemia is the reason for more than 20% of the mortality out

of 510 000 maternal deaths recorded per year secondary to childbirth or early post-partum in Ethiopia.⁶

Anemia is linked with various unfavorable health consequences, such as increased mortality and cognitive disorders.⁷ The main physiologic effect of anemia is manifested by lower oxygen delivery to tissues, creating both compensatory responses and immediate or long term adverse health outcomes including poor growth, decreased activity, impaired cognitive performance, behavioral, motor development, and

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limited cardiovascular reserve.^{1,8} For example, more than 89% of all anemia-related disabilities are arising from least developed nations.⁷

Anemia can be caused by many different factors and iron deficiency anemia is thought to be the most common cause globally. Other causes that can result in anemia include nutritional deficiencies (including folate, vitamin B12, and vitamin A), parasitic infections, and inherited or acquired disorders that affect hemoglobin synthesis, red blood cell production, or red blood cell survival.¹ The anemia of inflammation is the other significant cause of anemia after iron deficiency anemia which can be resulted from exposure to different air pollutants emitted from high polluting energy sources such as biomass fuels. A finding that has used a wide range of data from multiple least developed nations indicated that both moderate and high exposure to biomass fuel smoke was linked with moderate/severe anemia in children.⁹ These fuel types (biomass fuels from wood, straw, crop residues, and dung) which are capable of producing noxious gases when burned are commonly used by households in most developing countries as the primary source of energy for cooking, heating, and lighting.¹⁰

Almost 3 billion people worldwide are dependent on biomass fuel for their energy needs,¹¹ and around 500 million households depend on kerosene to meet their household-level energy needs.⁷ The exposure of a pregnant woman to indoor air pollution from biomass fuels and kerosene during cooking meals and other tasks put the pregnant women and the developing fetuses at risk of potentially harmful environmental pollutants.^{7,12}

This risk of exposure to biomass fuel and kerosene will put pregnant women at a greater risk because women spend an enormous amount of time near to the pollutants. After all, cooking is a task mostly left for women even during at the time of pregnancy.⁹ This will most likely put the pregnant women at higher risk of developing adverse pregnancy outcomes including low birthweight, still birth, and anemia.¹²⁻¹⁶ There was limited researches regarding the association between indoor air pollution from different fuel types and the anemia status of the pregnant women in developing countries except 1 study done in India, where exposure to indoor air pollution from solid fuels was found to be associated with the anemia status of the pregnant women compared to pregnant women who were using clean or low polluting fuel types.¹⁰ Therefore, our research intends to determine the association between exposure to indoor air pollution from different fuel types and the anemia status of pregnant women in Ethiopia.

Methods

Study Area and Period

We have used the 2016 Ethiopian Demographic and Health Survey data which covers the whole country with a nationwide representative sample. Ethiopia is found in East Africa

which is divided into 9 regions (Oromiya, Amhara, SNNPR, Benishangul-Gumuz, Tigray, Afar, Somali, Gambela, and Harari) along with 2 city administrations (Addis Ababa and Dire Dawa) which is further sub-divided into zonal administration then into Woreda for administrative purpose. The Woreda is also divided into kebele which is the smallest administrative unit. The country has a total population of about 100 000 000 with 1 100 000 km² area in 2018 based on United Nation latest estimates making the country the second-most densely populated country in the continent of Africa.

Study Design, Sampling Technique, and Data Collection

This is a cross-sectional study that was conducted using the Ethiopian demographic and health survey (DHS) data conducted in 2016. This survey has been carried out by the Ethiopian central statistics agency (CSA) every 5 years with the major aim of gathering timely estimates of key demographic and health indicators with the Ministry of Health's (MoH) request and this is the fourth round. The survey was conducted by ICF technical assistance. The census frame is a complete list of 84 915 enumeration areas (EAs) created for the 2007 PHC. Two-stage stratified sampling was used to select eligible residential households across 645 enumeration areas (EAs). Each region was stratified into urban and rural areas, giving 21 sampling strata. Samples of EAs were selected independently in each stratum in 2 stages.

Dependent Variable

The information gathered about the hemoglobin level was the basis for categorizing the anemia status of the included pregnant women. Blood specimens for anemia testing were taken from voluntarily consented pregnant women and a drop of blood was captured from a finger prick and collected in a microcuvette. The Analysis of Hemoglobin level was done on-site using a battery-operated portable HemoCue analyzer and the concentration of hemoglobin from each sample was measured in g/dl. The criteria developed by WHO were applied to categorize the pregnant women's anemia status based on their hemoglobin (Hb) level as not anemic (Hb ≥ 11 g/dl), mildly anemic ($10 \text{ g/dl} \leq \text{Hb} < 11 \text{ g/dl}$), moderately anemic ($7 \text{ g/dl} \leq \text{Hb} < 10 \text{ g/dl}$), or severely anemic ($\text{Hb} < 7 \text{ g/dl}$).¹⁷ Based on this we categorize the mothers as not anemic and anemic. Those anemic mothers were also further categorized by the severity of anemia status as severe, mild, and moderately anemic.

Exposure Variable

The type of fuel used in the household where the pregnant women live was the main exposure variable of interest. The

households were explored for the type of fuel they used by interviewing the pregnant women the question “What type of fuel does your household mainly use for cooking?”. The options for the response were electricity, liquefied petroleum gas (LPG), natural gas, biogas, kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crop, animal dung, no food cooked in the household, and others. Therefore, the above mentioned different fuel types were further were classified by considering the type of indoor air pollution they produced as described in Mishra et al,¹⁸ as high pollution fuels (wood, straw, animal dung, and crop residues), medium polluting fuel types (kerosene and charcoal), and low pollution fuels (electricity, liquid petroleum gas, and natural gas).

Other Predictor Variables

Variables that are associated with anemia in other literature were included in this study as predictor variables. These age of the pregnant women, BMI, education level parity, residency, and wealth index. Maternal age was categorized as (15-24, 25-34, and 35-49 years). BMI of the pregnant mother was grouped as underweight, normal, overweight, and obese based on the weight over height square value >18.5 , 18.6 to 25, 25.1 to 29.5, and above 29.6 respectively. The highest education level achieved by the pregnant women was labeled as no formal schooling, primary school, secondary, university/college. The parity that excluded the current pregnancy was designated as 0, 1 (which includes 1 and 2 children), 2 (includes 3 and 4 children), and 5 or more.

The data regarding the pregnant women's exposure to household tobacco smoke was collected using the following question, “How often does anyone smoke inside your house? Would you say daily, weekly, monthly, less than monthly, or never?”⁵ and was handled as a 5-level categorical variable. The residency was coined into urban and rural and the wealth index was put into 3: poor, medium, and rich groups.

Inclusion and Exclusion Criteria

The number of currently pregnant mothers was 1135 from the total of 15683 mothers included in the survey. Out of these mothers whose hemoglobin was measured was 1088. Mothers who do not cook in the house and the pregnant women who were not part of the iron supplementation program during pregnancy were excluded which gives the final included cases of 732 (Figure 1).

Ethical Considerations

This study used secondary data for the analysis. It only used the household and maternal characteristics data without the identity of the respondents being known or made public. Therefore, it was exempted from ethical review approval.

However, a request was made to DHS was made, and a permission letter was granted to utilize the data set.

Data Analysis

Descriptive statistics was used to report the distribution of the data among variables using frequency and percentage. Tables, figures, and charts were used for data presentation. We have used STATA analysis software version 14 for data analysis. Binary Logistic regression model was fitted and was employed to determine whether there is an association between independent variables with the anemia status during pregnancy. Variables having a P -value of $>.20$ where entered into a multivariable model to determine the association between the use of different fuel types with anemia while adjusting for other potentially confounding variables. Hosmer and lameshow goodness of fit test was used to check for model fitness ($P > .05$). Adjusted Odds Ratio was used to measure the association and their 95% Confidence Interval was calculated. A P -value of less than .05 was considered for statistical significance.

Results

Characteristics of Participants

The total number of women interviewed in EDHS 2016 was 15683 from a total of 16583 sample size which yields a response rate of 95%. From these 1135 were currently pregnant. Among all currently pregnant interviewed in the EDHS 2016 hemoglobin was measured for 1067.

The majority of the mothers did not attend school for both groups (35.4% of low polluting fuel type users and 54.2% of solid fuel type users). A greater percent (25.8%) of clean fuel users have achieved higher education levels when compared to biomass users (2.2%). Almost all mothers were not exposed to household tobacco smoking among the low polluting fuel users and 97.2% of solid fuel users also were not exposed to tobacco smoke. The majority of the mothers had 1 or 2 children among both groups (53.3% and 36.2% for clean fuel users and biomass users respectively).

Anemia Status in Pregnant Women Across Different Fuel Type Users

As indicated in (Figure 2), from the included mothers, the proportion of all forms of anemia (with blood hemoglobin level <11 g/dl) in pregnant women in Ethiopia was found to be 40.44%, out of which 17.08% were mildly anemic, 19.67% were moderately anemic, and 3.69% were severely anemic.

The proportion of anemia in the low, middle, and high polluting fuel users was 13.6%, 46%, 40.9% respectively (Table 1).

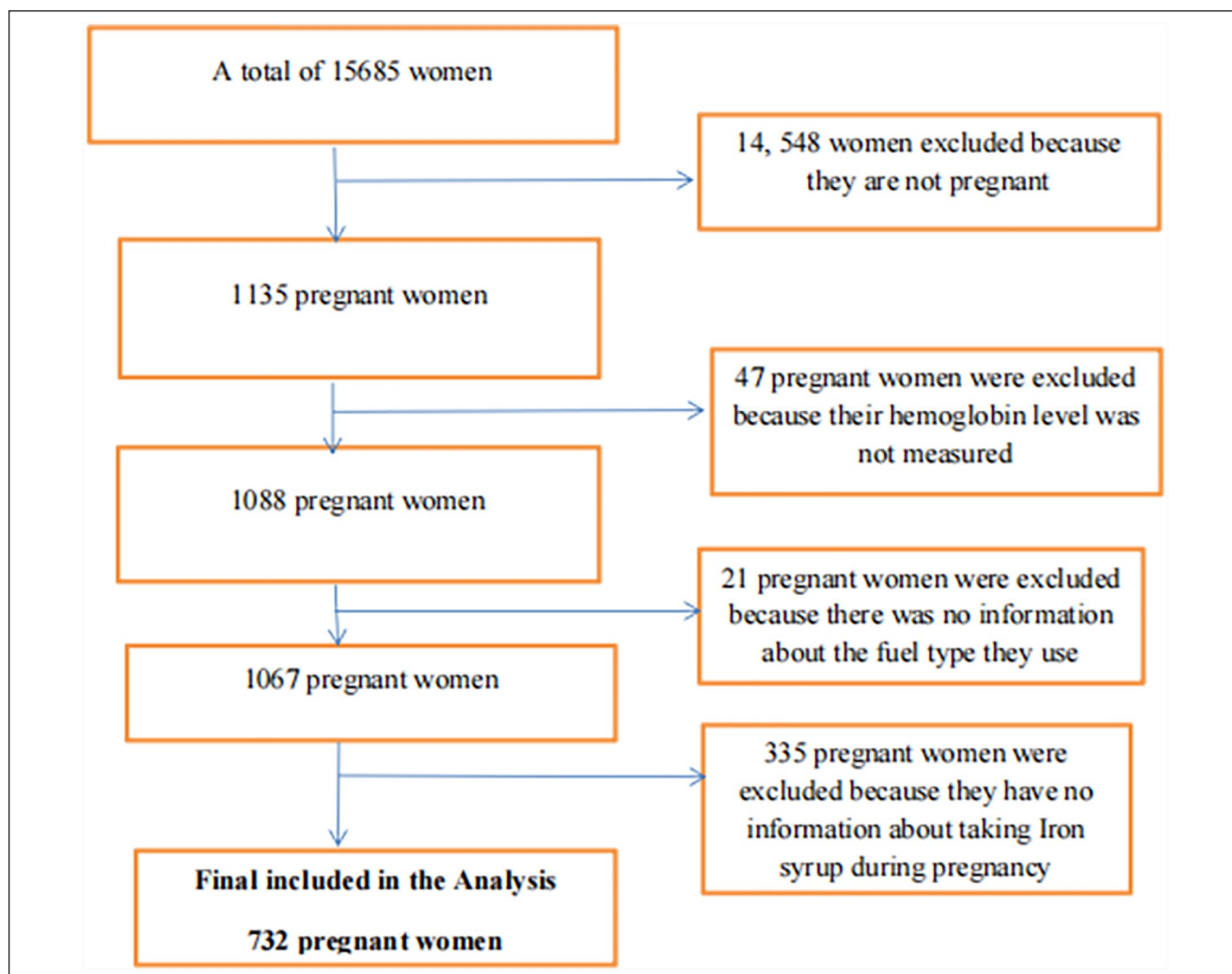


Figure 1. Included and excluded cases for the study.

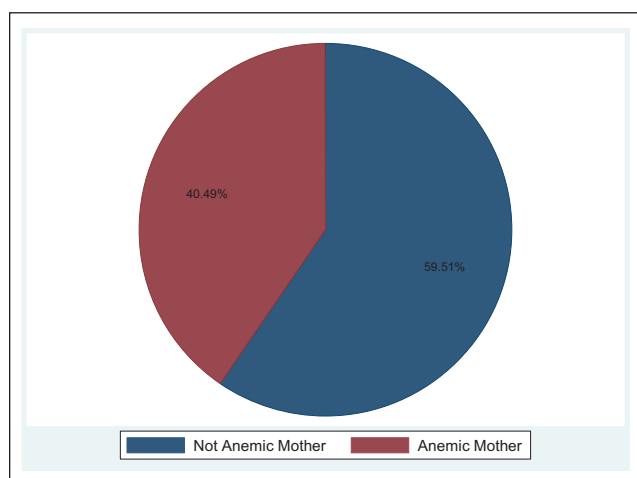


Figure 2. The proportion of overall anemia among pregnant women in Ethiopia.

Table 1. The Proportion of Anemia in Pregnant Women Among Different Fuel Type Users in Ethiopia.

Type of cooking fuel	Anemia level		Total
	Not anemic	Anemic	
Low	19	3	22
Medium	27	23	50
High	390	270	660
Total	436	296	732

Bivariate Analysis

In the bivariate analysis, the use of high and medium polluting fuel types had a significant association with the anemia status of the pregnant women (Table 2). Educational level, wealth index, and duration of pregnancy were also predictors of anemia among pregnant women in the bivariate analysis.

Table 2. Descriptive Summary and Bi-Variable Analysis for Anemia Status in Pregnant Women in Ethiopia, EDHS 2016.

Covariates	Co-variables	Frequency (%)	COR [CI for COR]	P-value
Age of pregnant women	15-24 Years	216 (29.51)		
	25-34 Years	395 (53.96)	0.74 (0.53, 1.03)	.075
	35-49 Years	121 (16.53)	0.79 (0.504, 1.24)	.31
Place of residence	Urban	96 (13.11)		
	Rural	636 (86.89)	1.21 (0.78, 1.89)	.395
Educational level	No education	488 (66.67)		
	Primary	186 (25.41)	0.6 (0.42, 0.85)	.005
	Secondary	34 (4.64)	0.88 (0.44, 1.78)	.73
	Higher	24 (3.28)	0.42 (0.16, 1.07)	.071
Given iron pills/syrup	No	458 (62.57)		
	Yes	274 (37.43)	0.77 (0.56, 1.05)	.093
Wealth index	Poor	443 (60.52)		
	Middle	104 (14.21)	0.51 (0.32, .80)	.004
	Rich	185 (25.27)	0.62 (0.43, 0.88)	.008
Smokes cigarettes	Not smoke	721 (98.5)		
	Smoke	22 (1.5)	1.23 (0.37, 4.07)	.733
Duration of current pregnancy	1-3 Months	141 (19.26)		
	4-6 Months	287 (39.21)	1.22 (0.80, 1.86)	.351
	≥7 Months	304 (41.53)	1.59 (1.05, 2.4)	.029
No. of children 5 and under	No child	39 (5.33%)		
	One child	337 (46.04)	0.75 (0.38, 1.48)	.414
	≥2 Childrens	356 (48.63)	1.23 (0.63, 2.4)	.549
No. living children	No parity	16 (2.19)		
	<4	427 (58.33)	0.79 (0.29, 2.17)	.653
	≥4	289 (39.48)	0.99 (.36, 2.74)	.991
Type of cooking fuel	Low	22 (3.01)		
	Medium	50 (6.83)	5.4 (1.41, 20.58)	.014
	High	660 (90.16)	4.4 (1.28, 14.96)	.018

Multivariable Logistic Regression

In the multivariate logistic regression, after controlling for the possible co-founders, the result indicated that fuel type was 1 significant factor for the anemia status of the pregnant women in Ethiopia. The use of medium polluting fuels such as kerosene and charcoal was associated with having 4.6 times (AOR; 95% CI: 1.41-18.35) more chance of being anemic than the use of low polluting fuels. Those women who were found in their third trimester were found to be 1.72 times (AOR; 95% CI: 1.12-2.64) more anemic than those women who were found to be in the first trimester as shown in (Table 3).

Discussion

In resource-poor settings, the concurrence of anemia at the time of pregnancy is a common and major public health problem that affects 30% to 60% of pregnant women which is also associated with unfavorable consequences for the pregnant women and the child.¹⁹ To our knowledge and literature search, no other finding has been previously done to assess the association between the use of different fuel types

on the outcome of anemia in pregnant women in Ethiopia. According to our finding, from the selected pregnant women the proportion of anemia was 40.44% where a high proportion of its inhabitants rely on biomass fuels,⁵ of which are highly polluting. Consequently, we hypothesize the use of biomass fuel affects the outcome of anemia in pregnant women in Ethiopia. Hence, the use of medium polluting fuel types was associated with higher risks of being anemic in pregnant mothers, controlling for maternal age, BMI, education level, and supplementation of an iron tablet.

The proportion of pregnant women who were found to be anemic altogether was 40.44% of which 9.9% were moderately anemic; 16.6%, mildly anemic; 2.2%, severely anemic. The finding was somewhat in line with the similar findings reported from Mangalore (41.5%)²⁰ and slightly lower than with the studies done in Northern Ghana (42.7%).²¹ On the other hand, this prevalence was higher than studies conducted, in South-East Ethiopia, (27.9%),²² Gondar town (22%),²³ Sudan (10%),²⁴ and Iran (13.6%).²⁵ The variations may arise mainly due to geographical variation across different areas and differences in socioeconomic status. The dereference in the proportion of low polluting

Table 3. Multivariable Analysis for Anemia Status in Women with Pregnancy in Ethiopia, EDHS 2016.

Covariates	Anemia level		Odds ratio	P > z	[95% CI for AOR]	
	Not anemic	Anemic				
Age of pregnant women						
15-24 Years [®]	118	98				
25-34 Years	244	150	.732	.083	.512	1.037
35-49 Years	73	48	.746	.223	.465	1.20
Educational level						
Higher [®]	18	6				
No education	271	216	1.613	.378	.557	4.676
Primary	126	60	1.01	.990	.345	2.936
Secondary	20	14	1.82	.322	.556	5.962
Given iron pills/syrup						
No [®]	262	196				
Yes	173	100	.809	.199	.581	1.12
Wealth index						
Rich [®]	122	63				
Poor	240	202	1.372	.145	.896	2.102
Middle	73	31	0.766	.346	.440	1.334
Trimester						
First trimester [®]	93	48				
Second trimester	175	111	1.332	.197	.856	2.042
Third trimester	167	137	1.72	.013	1.12	2.640
Type of cooking fuel						
Low [®]	19	3				
Medium	27	23	4.586	.032	1.144	18.40
High	389	270	2.731	.140	.719	10.37
Constant			0.317	.113	.0770	1.312

fuel types users and dietary habits of the study participants could also contribute to the variation.

In this study, the use of medium polluting fuel types and biomass fuels (high polluting fuels) was associated with anemia during pregnancy in the bivariate analysis, and only medium polluting fuel types were linked with being anemic during pregnancy which was more or less in line with the findings from other developing countries such as India,⁹ which described that being exposed to solid fuels was a determining factor the outcome of anemia when compared with those pregnant women who were using clean or low polluting fuel types.

The association of fuel types with anemia among pregnant mothers is physiologically reasonable on account of the potential role of the gaseous pollutants emitted from medium and high polluting fuels, in triggering systemic inflammation, caused by which could finally lead to iron homeostasis, impaired erythropoietin response to reduced hemoglobin levels, and impaired marrow response to erythropoietin.²⁶ Long-term exposure to minimal concentrations of air pollutant gases (such as pollutants from biomass fuels and kerosene) can easily affect the hematopoietic system by interfering in the formation of red blood cells and the

process of formation of heme, during the formation of red blood cells.^{27,28} Air pollutants from the burning of polluting fuels may lead to significant damage to red blood cells such as reduced hemoglobin concentrations, the number of erythrocytes, and hematocrit, thus leading to anemia.^{29,30}

High indoor air pollution is a known risk factor for structural lung diseases especially chronic obstructive pulmonary disease (COPD) and the resulting chronic hypoxia stimulates red cell production masking underlying anemia.³¹ This could be one of the possible explanations for the result that high pollution caused less anemia as compared to medium pollution.

In our study, the association between anemia in the time of pregnancy and biomass fuel might be obscured by the wealth index. The use of cleaner or low polluting fuel types for household energy needs is more expensive than high polluting fuel types. In the Ethiopian context biomass fuels, such as cow dungs and other agricultural by-products are either cheap or free while fuel types such as electricity, liquid petroleum gas, and natural gas which are not only relatively expensive, rather should be accessible to use them.

Pregnant women who were in their third trimester were 1.72 times (AOR 1.72; 95% CI: 1.12-2.64) more likely to

be anemic than women who were in the first trimester. This finding was in line with the findings reported in other studies,^{32,33} where Pregnant women who are at third trimesters were found to be more anemic than women who are at their first trimester. Pregnancy by itself is one known cause of anemia that resulted from the body's biological changes associated with pregnancy mainly because of the unbalanced flow of blood volume with that of the total red blood cell mass distribution, creating what is called dilutional or physiological anemia of pregnancy.³⁴ It could also be due to the physiologic processes occurring during pregnancy that might lead to a higher maternal plasma volume increment (40%-50%) relative to red cell mass (20%-30%) which accounts for the fall in hemoglobin concentration.³⁵

Since each pollutant emitted from different kinds of fuel types pauses different effect on the pregnancy outcome the result of this assessment should be utilized with great care. Further studies which assess the exposure assessment of each indoor air pollutant chemical with its outcome must be assessed before concluding.

Strength and Limitation of This Study

Since we have used nationwide data for our study the conclusions can also be at the country level which the authors assume is the strength of this study. The data regarding the pregnant women's exposure to a single or multiple pollutants, continuous or one time; the presence of other additional exposure other than the polluting fuel such as presence or absence of atmospheric pollution are not included in this study. The use of improved cookstoves and the ventilation status of the cooking environment are other factors that are not included but have the potential to alter the outcome of the study variable at hand. As a result, exposure and outcome data may not be precise and might indicate a different outcome.

Conclusion

According to the result of this research pregnant women who live in a household that uses kerosene and charcoal for household energy needs have a higher chance to be more anemic when compared with pregnant women who reside in households that use low polluting fuels in Ethiopia. In a country where majority of the population uses medium to high polluting fuel types urgent intervention is needed to reduce the indoor air pollution that is associated with adverse pregnancy outcomes such as anemia.

Declaration of Conflicting Interests

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