Health risk perceptions of household air pollution and perceived benefits of improved stoves among pregnant women in rural Ethiopia: a mixed method study

Demelash Habtamu,1 Beyene Abebe,2 Tiku Seid2

ABSTRACT

Objective Since community perceptions of the risk of biomass smoke and the benefits of improved stoves play a critical role in behaviour change to the uptake and sustainable utilisation of improved stoves, we aimed to assess the level of health risk perception on kitchen smoke and benefits of using improved stoves among pregnant women.

Design A community-based cross-sectional mixed method study.

Setting In six kebeles of a low-income rural community of South Gondar Zone, Northwestern Ethiopia.

Participants All 455 households with pregnant women aged 18–38 years, in their first-trimester or second-trimester gestation, exclusively use traditional biomass-fuelled or locally modified mud stoves, and the primary cook in her household were included. But completed data were obtained only from 422 households.

Result From 422 completed data, more than half, 63% (95% CI 58% to 68%) had high-level health risk perception of household air pollution, and nearly three-fourths, 74% (95% CI 70% to 79%) of the respondents perceived that using improved stove had benefits for their families. Participants in the 32–38 years age group, rich in asset index, presence of under-five children, being a member of any women group and large family size were positively associated with high-level health risk perception. Whereas respondents in the 18–24 years age group, presence of under-five children, husbands of primary or higher education, high health risk perception and not happy with the current stove were positively associated with perceived benefits of using an improved stove.

Conclusion The observed level of health risk perception of biomass smoke and the benefits of using improved stoves may help to adopt effective intervention measures. This study also suggests that for successful intervention, clean cooking programmes and policies must consider many local factors influencing health risk perception and benefits of using improved stoves.

Trial registration number ACTR202111534227089.

INTRODUCTION

Burning of solid biomass fuels in inefficient and highly polluting stoves for cooking emits high levels of harmful air pollutants that affect health throughout the life course.1–4 A growing body of both epidemiological and toxicological studies links household air pollution (HAP) with increased risks of several acute and chronic health conditions5–9 and adverse pregnancy outcomes.10–13 The rate of these health burdens remains high in low-income and middle-income countries (LMICs), particularly in southeast Asia and sub-Saharan Africa.14–18 In Ethiopia, where >95% of the energy is supplied by solid biomass sources, cooking smoke was associated with various health problems.5,17–19

The common public health intervention efforts aimed at reducing HAP exposure and related health burdens have been focused mainly on the distribution of improved stoves and clean fuels.50–23 WHO suggested...
improved stoves be prioritised for clean cooking transition and there have been several efforts to promote improved biomass cookstoves in many parts of the world. The global alliance for clean cookstoves has set goals to distribute 100 million cleaner and more efficient stoves by 2020. Furthermore, the world bank and East Asia and Pacific region’s clean stov initiative have launched several regional clean cooking initiatives to promote, disseminate and adoption of clean cooking solutions for rural poor households.31 32

Similarly, bearing in mind that solid biomass fuel is likely to remain the dominant source of energy for cooking throughout the country for the foreseeable future, the Ethiopian government gave attention to the importance of improved stoves to reduce demand for firewood and health burden.33 As a result, the federal government has proposed to distribute 30 million house holds with improved stoves by 2030 to reduce the demand for biomass fuel and related smoke by increasing fuel efficiency as a strategic priority.35 36 The National improved cooking stove programme was designed to implement the government plan in distributing improved stoves through a sustainable and vibrant market.37

Unfortunately, most of these interventions have followed a top-down approach, ignoring the social and cultural context which perpetuates a one-size-fits-all mentality.38–39 As a result, various initiatives which have been attempting to distribute improved cooking stoves over the past few decades demonstrated little evidence of health benefits mainly due to incomplete adoption and stove staking (concurrent use of traditional and improved stoves).40 41 42 43 Poor understanding of the socio-cultural context is the main factor identified for the poor adoption of stoves.16 44 45 In addition, the perception of the community on the health risk of HAP and the benefits of improved stove intervention is fundamental for risk communication and determining which hazards people care about and how they deal with them.46 47

Although efforts have been made to disseminate various improved stoves by governmental and non-governmental organisations in Ethiopia at large and the Amhara region in specific, it remains tough to achieve the adoption of improved cook stoves for wider utilisation.48 49 Since the local cooking practices, health risk perception of HAP and perceived benefits of improved stoves are expected to enhance the success of the intervention effort,42 43 this research uses the baseline data from the main trial study to assess the common cooking practice, level of health risk perceptions and perceived benefits of improved stoves for promoting exclusive adoption of improved stoves.

MATERIALS AND METHODS

Study setting

The study was conducted in the rural community of Guna-Tana integrated field research and development centre of Northwestern Ethiopia located approximately 657 km northwest of Addis Ababa, from 15 November to 27 December 2022. The field research centre was established in 2013 by Debre Tabor University to integrate education, research and community services. It is bounded by Guna Mountain in the east, Lake Tana in the west, Ribb River in the north and Gumara River in the south. The research centre slopes gradually to Lake Tana, which is the largest lake in the country with 1500 m above sea level (online supplemental figure 1).51

The study setting comprises 10 kebeles (the smallest administrative unit) deliberately selected to represent the research area in terms of various characteristics from three districts (Guna, Farta and Fogera). The kebeles were selected based on their unique three climatic conditions, namely Dega (the coldest highlands >3500 m), Woina Dega (the medium highlands from 2500 to 3500 m) and Kolla (warm lowlands between 1500 and 2500 m). But for this research, kebeles in Fogera district were excluded due to high malaria prevalence in the area which may affect the birth outcomes (for upcoming stove trial study) or to avoid additional costs for insecticide-treated bed net distribution and malaria test. But malaria is not common in the remaining two districts due to high elevation.

This study recruited pregnant women from two ecological zones (cold and temperate) to represent a diversity of characteristics expected to influence the cooking practice and perceptions of the community, including altitude, population density, cooking practices, fuel types and socioeconomic conditions. The population is typical of many rural poor communities in the region and will therefore have reasonable generalisability and wide relevance to the study. Since tobacco smoking and vehicle emission are not common, and biomass fuel use with traditional three-stone stoves is a widespread practice in the study community, kitchen smoke from biomass burning is the main source of HAP exposures in the study area.

Study design

As part of the stove trial research in Guna-Tana integrated research and development centre of south Gondar Zone, Northwestern Ethiopia (https://pactr.samrc.ac.za/Identifier: ACTR202111534227089), a community-based cross-sectional mixed methods study was employed to determine the local cooking practices and perceptions towards the health risk of HAP and benefits of using improved stove among pregnant women. Quantitative and qualitative research methods combined into a convergent parallel design to gain insights for the upcoming stove intervention study. The level of integration occurred at the results interpretation step to understand if qualitative findings converge or diverge from quantitative ones. This kind of mixed research design is recommended especially in LMIC settings, where understanding social, economic and cultural contexts are essential to enhance the effectiveness of various health interventions.52

Study population

All households in the selected kebeles with pregnant women who fulfilled the eligibility criteria were recruited.
To identify candidate pregnant women, the field data collectors worked in collaboration with nearby health posts, health centres and community health development leaders in the study areas. To be eligible and participate in this study, a pregnant woman must meet the following inclusion criteria: aged 18–38 years, in her first or second-trimester gestation (gestational age ≤24 weeks) which was determined by the self-reported first day of the last menstrual period and ultrasound, exclusively use a traditional biomass-fuelled stove or locally modified mud stove and the primary cook in her household. But, pregnant women, lactating women and young newly married girls were included in the qualitative part mainly to generate a diverse range of opinions on HAP and related health problems.

**Sample size determination**

Based on a single population proportion formula for cross-sectional study design considering a confidence level of 95%, the absolute precision of 5% and 20% of women perceived that biomass fuel use affect the health of their children from the previous study. Considering 1.5 design effects and a non-response rate of 10%, the final sample size was determined to be 406 pregnant women. But, since we had the advantage of using all the baseline data from an ongoing randomised controlled trial of an improved stove project (https://pactr.samrc.ac.za/Identifier Identifier: ACTR20211154227089), we considered all pregnant women to attain the larger sample size which would increase the accuracy of estimations. Based on the actual data from the district health offices and local health extension workers’ records, there were 455 eligible pregnant women in 5 kebeles.

**Patient and public involvement**

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Variables, context definitions and assessment methods**

**Health risk perception of HAP**

In this study, a woman’s health risk perception of HAP is defined as a woman’s subjective judgements or view of the risk of receiving a health problem from HAP or their self-belief of the chances of contracting a certain health condition due to HAP. The health risk perception was determined through eight questions with a 5-point Likert-scale response coded as: ‘strongly agree’=5, ‘agree’=4, ‘neither’=3, ‘disagree’=2 and ‘strongly disagree’=1. This response format with more choices is preferable to explain more variance. Participated pregnant women were asked to rate their level of agreement with the statements regarding diseases or illnesses associated with HAP. The scale was scored positively and classified as low perceived risk and high perceived risk for further analysis.

**Perceived benefits of an improved stove**

The degree to which a woman believes that using an improved stove would reduce time, fuel and her exposure to HAP and related health burden. It was measured using six questions with response categories from ‘strongly agree to strongly disagree’. The respondents were asked to rate their level of agreement on six statements regarding the benefits of using improved stoves. The possible scores for scale ranged from 6 to 30 points with higher scores indicating greater perceived benefits. The reliability of this scale was established and Cronbach’s alpha was 0.6, demonstrating accepted reliability.

**Family size**

Family size is expected to influence the exposure status of the women to biomass smoke due to the high frequency of cooking per day and cooking a high volume of food per day. The total number of individuals permanently living in the household was assessed by recording all individuals (male, female, under-five children) and further categorised as (a) fewer than five individuals and (b) greater than or equal to five individuals. The grouping was made based on Ethiopia’s average family size.

**Educational status**

Since educational status has a potential role to influence the health risk perception of HAP and perceived benefits of using an improved stove, then the cooking practice was assessed based on three classifications as (a) unable to read and write, (b) read and write only and (c) primary and above school completed.

**Asset index**

As socioeconomic status (SES) is linked to a wide range of health problems, we assessed the SES of the respondents in terms of asset index. The asset index is recommended than using income or expenditure to characterise the SES of the respondents as it is less susceptible to short-term economic shocks and likely a better proxy of long-term household wealth. The ownership of 12 assets (radio, mobile, watch, solar, modern bed, cows, oxen, hens, chairs, goat/sheep, farmland, bank account) and 3 household utilities (main drinking water sources, toilet type and kitchen type) were collected to construct a composite index representing the SES. These assets and utilities were selected based on their local value and importance to distinguish relatively ‘wealthy’ households and relatively ‘poor’ ones. Four variables/assets (cycles, horses, carts and honey bees) were excluded from the analysis as these assets were owned by <5% of the respondents. The asset index was estimated using principal component analysis (PCA) and divided into three quintiles, ranking from the poor to the rich.

**Kitchen location**

In addition to cooking practices, the kitchen is the most likely area for families to congregate and discuss the details of their days with each other which determines the exposure status of an individual. Kitchen location was assessed through observation and classified into (a) separated from the main house, (b) attached to the main house, (c) separated from the main house and (d) attached to the main house.
house, (c) in the living house and (d) open fire without a kitchen.

Primacy fuel use
The various fuel options for cooking emits different amount of pollutants in the same kitchen. The most commonly used fuel types for domestic use were assessed through options (a) firewood, (b) cow dung, (c) agricultural residue and (d) charcoal.

Multiple fuel use
Using more than one fuel per cook is expected to emit more pollutants than using a single fuel. In this study, multiple fuel use was assessed by providing spaces to list the most common fuel mix used during dry and rainy seasons. Finally, the frequency was calculated for each common fuel mix.

Cooking frequency
The number of lighting the fire per day affects the exposure status of the main cook. Cooking frequency was assessed by classifying (a) once per day, (b) twice per day, (c) three times per day and (d) four and more times per day.

Frequency of injera baking
Injera is a flat bread-like pancake prepared from a tiny grain called teff. It is Ethiopian staple food and very energy intensive to cook which uses for approximately 50% of all primary energy consumed in the household. The frequency of baking injera was assessed with categories of (a) once per week, (b) twice per week and (c) three and more times per week.

Data collection
In the quantitative study, face-to-face interviews using structured questionnaires and observational checklists were conducted by trained first-degree environmental health professionals. The questionnaires were adopted from different kinds of literature and pretested on 20 pregnant women before being used in the actual study. The topics included in the question were participants’ social and economic characteristics, housing conditions, kitchen and stove condition, fuel type and cooking behaviour, perceptions of health risks of HAP and perceptions towards the benefit of improved stoves. The questionnaires were administered in the local language (Amharic).

In addition, qualitative data were collected through focus group discussions (FGDs) modulated by two public health experts with appreciable experiences in qualitative data collection. To generate a diverse range of opinions on the fuel type, perception of HAP and related health problems and perceived benefits of using improved stoves, pregnant women, lactating women and young newly married girls were included in the FGDs. In total, four FGDs comprising six to nine participants with an age range of 18–43 years were conducted. The discussion themes were framed as common fuel types, seasonal variation of fuel types, health risk perception of HAP and perceived benefits of improved stoves. Each FGD line of discussion was stopped at the saturation point (when no new information was generated regarding the prespecified themes).

Data quality control
The training was given to both quantitative and qualitative data collectors and supervisors separately by the investigators. Data collectors were recruited based on their familiarity with local culture and norms, mainly to promote friendly dialogue during the data collection process. Data collectors reviewed each question carefully and conducted a pretest in the study area but at a different kebele, before the actual study commences. The pretest was aimed at establishing an approximate time needed to administer the questionnaire without causing distress to the participants as well as obtain feedback on the appropriateness of the content and accuracy of the translations. The responses obtained were analysed using a PCA to test the contribution of each question to the perceived health risk of HAP and perceived benefits of improved stoves using component correlation coefficients. This measure was used to identify irrelevant questions, which were then removed. Based on the feedback, some important dichotomous variables were prerecorded and provided as options for responses. The investigators and data collectors checked the final version of the questionnaire and updated it as required based on the pretest. In addition, the qualitative data collection was conducted on appropriate days and places to avoid the unnecessary rush by the discussants and modulators. Women without any marked hierarchical link between them were recruited and participated in the FGD.

Data processing and analysis
Before formal statistical analyses, the collected data were processed to make it suitable for further analysis. This includes coding and recoding, checking the completeness, cleaning and sorting through simple tabulations and graph construction mainly to gain a good understanding of the data. Then, descriptive statistical analysis was conducted for demographic and other characteristics to elucidate basic features in the data and to identify gross outliers. Logistic regressions were used to detect any association between health risk perceptions of HAP and perceived benefits of improved stoves with socioeconomic and other housing or cooking-related variables. The independent variables consisted of educational level, age groups, asset index and other relevant socioeconomic variables. The significance level was set at p value <0.05 with a 95% CI for the OR.

The Hosmer-Lemeshow goodness-of-fit test was used to check the model fit and multicollinearity was checked among independent variables using variance inflation factor at a cut-off point of 10. Data were analysed using Statistical Package for the Social Sciences software for Windows, V.24.0 (IBM, Armonk, New York, USA). The
The final report was organised following the Strengthening the Reporting of Observational Studies in Epidemiology checklist of items that should be included in reports of cross-sectional studies.62

Regarding the qualitative data, all audio-recorded FGDs were transcribed verbatim and translated into English by an experienced translator and analysed following a thematic analysis approach.63 The translated data were cross-checked with the audio file to ensure proper transcription and translation. The principal investigator read the translated data repeatedly to understand the concept and related meanings of the data. Line-by-line coding was done to identify related patterns. The codes with similar patterns were merged to identify themes from the data. During analysis, modifications to existing codes and themes were made based on the information from subsequent interviews.

RESULTS

Sociodemographic characteristics

In this study, a total of 455 pregnant women were approached but only 422 fully completed the questionnaire, making the response rate 93% and the percentage of missing answers from completed questionnaires was

Table 1  Housing characteristics and cooking practices among pregnant women (n=422) in South Gondar Zone, North Central Ethiopia

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Frequency (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of rooms in the living house</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One room</td>
<td>53</td>
<td>12.6</td>
</tr>
<tr>
<td>Two rooms</td>
<td>208</td>
<td>49.3</td>
</tr>
<tr>
<td>Three or more rooms</td>
<td>161</td>
<td>38.2</td>
</tr>
<tr>
<td>Number of windows able to open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No window able to open</td>
<td>140</td>
<td>33.2</td>
</tr>
<tr>
<td>Only one window</td>
<td>185</td>
<td>43.8</td>
</tr>
<tr>
<td>Two windows</td>
<td>75</td>
<td>17.8</td>
</tr>
<tr>
<td>Three and above windows</td>
<td>22</td>
<td>5.2</td>
</tr>
<tr>
<td>Location of cooking kitchen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separated from the main house</td>
<td>252</td>
<td>59.7</td>
</tr>
<tr>
<td>Attached to the main house</td>
<td>109</td>
<td>25.8</td>
</tr>
<tr>
<td>In the living house</td>
<td>14</td>
<td>3.3</td>
</tr>
<tr>
<td>Pen fire without a kitchen</td>
<td>42</td>
<td>10.0</td>
</tr>
<tr>
<td>Kitchen structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fur-walled kitchen structure</td>
<td>198</td>
<td>46.9</td>
</tr>
<tr>
<td>Three-walled kitchen structure</td>
<td>123</td>
<td>29.1</td>
</tr>
<tr>
<td>No walls, but a covered roof</td>
<td>95</td>
<td>22.5</td>
</tr>
<tr>
<td>Cooking in the same place all year round</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>234</td>
<td>55.5</td>
</tr>
<tr>
<td>No</td>
<td>188</td>
<td>44.5</td>
</tr>
<tr>
<td>Most frequently used stove type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three stone traditional stove</td>
<td>344</td>
<td>81.5</td>
</tr>
<tr>
<td>Other locally modified stoves</td>
<td>78</td>
<td>18.5</td>
</tr>
<tr>
<td>A perceived disadvantage of the traditional stove</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use lots of firewood</td>
<td>132</td>
<td>31.3</td>
</tr>
<tr>
<td>Takes a long time to cook</td>
<td>61</td>
<td>14.5</td>
</tr>
<tr>
<td>Emits lots of smoke</td>
<td>119</td>
<td>28.2</td>
</tr>
<tr>
<td>Difficult to light the fire</td>
<td>43</td>
<td>10.2</td>
</tr>
<tr>
<td>Not safe for cooking</td>
<td>58</td>
<td>13.7</td>
</tr>
<tr>
<td>Frequency of cooking per day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once</td>
<td>107</td>
<td>25.4</td>
</tr>
<tr>
<td>Twice</td>
<td>235</td>
<td>55.7</td>
</tr>
<tr>
<td>Thrice and above</td>
<td>75</td>
<td>17.8</td>
</tr>
<tr>
<td>Frequency of injera baking per week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once</td>
<td>69</td>
<td>16.4</td>
</tr>
<tr>
<td>Twice</td>
<td>341</td>
<td>80.8</td>
</tr>
<tr>
<td>Three and more times</td>
<td>11</td>
<td>2.6</td>
</tr>
<tr>
<td>Ever heard about improved stoves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>398</td>
<td>94.3</td>
</tr>
<tr>
<td>No</td>
<td>23</td>
<td>5.5</td>
</tr>
<tr>
<td>Reasons for not having an improved stove</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial constraints</td>
<td>144</td>
<td>34.1</td>
</tr>
</tbody>
</table>
relatively small (<5 %) for all variables. As shown in online supplemental table 1, most participants were between the ages of 25 and 31 years (mean age: 28.9±5.3 years). All participating pregnant women were Amhara by ethnicity, Orthodox Christian and most of them were currently married. Two hundred sixty-six (63%) of the participating women cannot read and write, with only 19% of the respondents having primary and above educational level. About 45% of the pregnant women were members of any women’s group in their respective villages. Regarding the family size, on average five individuals (4.5±1.6) permanently lived in the respondents’ household and 42% of the participants had on average one child aged under 5 years and only 31% of the participants belonged to the rich socioeconomic background of the asset index.

In our qualitative study, 25 women without any noticeable hierarchical link between them participated in the four FGDs. As shown in online supplemental table 2, the ages of the FGD participants ranged from 18 to 45 years (mean: 29.4±7.7 years). Most of them had primary and above education, were married and already had children. More than half of the discussants had less than five family sizes.

**Housing characteristics and cooking practices**

All study participants were living in earthen floors, wood/ mud walls and corrugated iron sheet roof homes. As shown in table 1, three-fifths of the households (60%) used separate kitchens from the main house and nearly half of them (47%) had four-walled enclosed kitchens in their yard. More than half (56%) of the respondents were cooking in the same kitchen all year round and the majority (82%) were using three stone stoves and solid biomass fuel for cooking and baking.

Firewood was the primary cooking fuel used by nearly three-fourths (76%) of the respondents. Seasonal variation in the type of biomass fuel was observed and it is the common practice to use more than one biomass fuel per cook in the study area which was reported by 78% of the respondents. Firewood and agricultural residue were the main fuel mix used in the dry season as reported by 45% of women. Whereas firewood and cow dung were the common fuel mix during the rainy season which was reported by 54% of women.

Moreover, more than half of the interviewed pregnant women (56%) reported lighting their stoves at least three times (for breakfast, lunch and dinner) per day and staying in the kitchen for an average duration of 2.5 hours per day. Whereas 81% of pregnant women were baking *injera* (Ethiopian staple food and flatbread-like pancake prepared from a tiny grain called teff) at least twice per week. In addition, most of the participating women (80%) have dried their fuel before use and only 44% of them intentionally open windows or doors while cooking.

In this study, more than three-fifths (64%) of the study participants reported their plan to buy and use the improved stove in the future. A significant number (94%) of the participants had ever heard about improved stoves, but, only very few of them (23%) had ever used any kinds of locally modified improved stoves.

Similarly, types of fuel commonly used for cooking and seasonal variation of cooking fuel use was one of the discussion themes in the qualitative part of this study. As in many LMICs, biomass fuels (mainly firewood and cow dung) form the most significant indigenous sources of rural household energy which is often gathered free of monetary cost by households.

...we usually use firewood, cow dung, and dried plant leaves as the main fuel to cook our food. But, cow dung emits more smoke than firewood and other fuels. Even firewood also can emit as much smoke if it didn’t get to dry properly. So for me, the solution is drying the firewood properly and not using cow dung as much as possible. (18–24 years old, FGD 1)

Based on the discussants’ view, crop residues, plant leaves and straw were mainly used during the dry seasons. As they mentioned repetitively, firewood and dried plant leaves are the main fuel combination used during the dry season whereas firewood and cow dung is the common biomass fuel mix used during the rainy season.

We usually collect wood and plant leaves for cooking during the dry season. But, during the rainy season, we use cow dung which has been prepared during the dry season and use it with firewood for cooking. During the dry season, since it’s sunny and everything is dry, and not difficult to start a fire but in the rainy season it’s very difficult to dry the fuels. So we have to prepare before the arrival of the rainy season. (32–45 years old, FGD 1) ... we are exposed to cooking smoke throughout the year but it is worsening in the rainy season since the firewood and cow dung become wet due to the rain. (32–45 years old, FGD 4)

It is also noticed that various solid fuels had different levels of pollution which affect the indoor air of the household. In this FGD, participants mentioned that cow dung produces more smoke than firewood and that levels were higher in the rainy season due to the high moisture content of biomass fuels.

... using cow dung as a cooking fuel worsens the emission of kitchen smoke. Due to that condition, I don’t use cow dung to cook food. Rather I’m using firewood and dried plant leaves as a main source of fuel to cook food. (25–31 years old, FGD 2) ... Using cow dung as fuel emits much more smoke than other types of fuels. But, now a day, most of us use the dung as a compost. So, we didn’t use cow dung as much as before. (25–31 years old, FGD 3)

It is also common to use additional fuel to start a fire in the kitchen. Paper and kerosene are commonly used to start a fire because they have low ignition temperature which helps to catch fire immediately and helps the wood or the dung to reach its required ignition temperature.
The discussants mentioned plastics, plant leaves, papers and kerosene as common fuels used to start the fire.

Most of the time, I used kerosene to start a fire during the rainy season. Because the firewood is wet so it is very difficult to start a fire without using kerosene. (18–24 years old, FGD 4) … I usually used paper and straw to start the fire (25–31 years old, FGD 2) …I use plant leaves to start a fire. First, I spread the leaves on the kitchen floor to dry them up the night before and use them to start a fire in the morning. (32–45 years old, FGD 2)

Health risk perception of household air pollution

The health risk perception of HAP was measured at the individual level by combining responses to eight questions that relied on 5-point Likert-scale items. Respondents were asked to indicate their degree of agreement or disagreement with each of a series of statements about the health risks associated with HAP exposure. The health issues listed in the survey were health problems, itching eyes, headache, acute respiratory infections (ARIs) and pneumonia in children, heart problems, high blood pressure/ hypertension and special susceptibility of women and children. Those items were chosen hoping to discriminate maximally between respondents and high perception scores represent perceived health risk associated with HAP compared with lower scorers respondents.

The Cronbach’s alpha internal reliability coefficient was estimated to determine whether the eight items (statements) of a scale measured the same underlying dimension (health risk perception). Accordingly, Cronbach’s alpha internal reliability coefficient was determined to be 0.76, indicating good internal reliability. The Cronbach’s alpha internal reliability coefficient ranged from 0.71 to 0.76 in the item deleted statistics.

Based on item-by-item (profile analysis), nearly three-fourths (72%) of the respondents certainly agreed with the general statement ‘Exposure to kitchen smoke from biomass fuel use can cause various health problems (37% strongly agreed and 35% agreed). Respondents were also asked about specific health risks associated with kitchen smoke and 73% of them agreed that kitchen smoke can cause itchy eyes (32% strongly agreed and 41% agreed), ARIs for children 70% (36% strongly agreed and 34% agreed), pneumonia in children 59% (30% strongly agreed and 29% agreed) and miscarriage or abortion among pregnant women, heart problems, high blood pressure/ hypertension and special susceptibility of women and children. Those items were chosen hoping to discriminate maximally between respondents and high perception scores represent perceived high health risk associated with HAP compared with other low scorer respondents.

Almost all community members in this village knew the health impacts associated with smoke emitted from the kitchen. It irritates the eyes and the particles in the smoke accumulates in the lung causing certain respiratory problems. It also causes dizziness and fatigue. But we have no choice other than using biomass fuels and traditional three-stone stoves to cook our food. (32–48 years old, FGD 2) … the smoke irritates the eyes then tears start flowing which leads to the growth of hair in the eyes which causes discomfort and pain. (18–24 years old, FGD 1)

Instead of respiratory health, the most frequently mentioned part of the body was the eye, which all FGD participants mentioned it.

...kitchen smoke causes irritation of the eyes that leads to the growth of hair in our eyes which is very painful and interferes with vision. (32–45 years old, FGD 1) … it irritates the eyes. (25–31 years old, FGD 2) … exposure to smoke cause eye irritation that results in discharge from the eye. The smoke causes blurring of vision and it’s difficult for me even to use a mobile phone. (32–45 years old, FGD 4)

The impact of HAP from biomass fuel use is disproportionately high among vulnerable segments of people. In their discussion, FGD participants tried to highlight the impact of kitchen smoke on pregnant women, especially those with underlying health conditions.

In an asthmatic woman, kitchen smoke exposure causes shortness of breath and exacerbation of asthmatic symptoms. In pregnant women, it harms both the mother and her unborn fetus. Exposure to extreme heat also causes dizziness in pregnant women and also harms their offspring inside. (25–31 years old, FGD 3) … too much kitchen smoke causes heart failure, fatigue, and dizziness even in non-pregnant women. We all believe that smoke emitted from cooking fuel causes various health problems in women and children. (25–31 years old, FGD 2)

It is a fact that women and children are disproportionately exposed to indoor air pollution due to biomass smoke generated in the kitchen during food preparation. Women took primary responsibility for cooking and children under the age of 5 years most often stayed with their mothers in the cooking area. FGD participants in this study also agreed with this fact.

...I carry my younger child on my back whenever I cooked food. The smoke irritates her eyes and predisposes my child to pneumonia. (25–31 years old, FGD 3) …off course we usually carry our kids while we are cooking food so they are equally exposed to kitchen
smoke. (25–31 years old, FGD 3) …. In pregnant ladies, it harms both the mother and her unborn fetus. Exposure to extreme heat cause dizziness in pregnant women and also harms the fetus inside. (32–45 years old, FGD 4)

Perceived benefits of improved stoves

In this study, respondents were asked to rate their level of agreement on six statements about the benefits people associate with improved stove use. Their perceived benefits were measured using a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) for positively worded statements. Positively worded and negatively worded items were used to control for participants’ tendency towards agreeing with responses. Scoring, then, is reversed on negatively worded items, so that all items can be meaningfully summed into one scale score. The possible scores for the scale ranged from 6 to 30 points with higher scores indicating greater perceived benefits of improved stove. The reliability of this scale was established and Cronbach’s alpha was 0.60, demonstrating accepted reliability.

Accordingly, nearly three-fourths (72%) of the respondents certainly agreed with the statement ‘using an improved stove has health benefits for the family’ (40% strongly agreed and 32% agreed). Similarly, 73% of the participants agreed that ‘using an improved stove can help to prepare many meals in a short time’ (38% strongly agreed and 34% agreed). Regarding fuel-saving benefits, 62% certainly agreed with the statement ‘improved stoves require less fuel than traditional stoves’ (27% strongly agreed and 35% agreed). Nearly two-thirds (67%) of the respondents certainly agreed (35% strongly agreed and 32% agreed) with the statement ‘improved stoves reduce the risk of burn injuries in children’. Around half of the study participants (53%) did not certainly agree with the statement ‘most people think that cooking with the improved stove is a sign of luxury’ (12% strongly disagreed, 16% disagreed and 25% neither agreed nor disagreed). Finally, 45% of the participants certainly agreed that food items cooked using an improved stove have the same or better taste than those cooked using traditional stoves (20% strongly agreed and 25% agreed) (figure 2).

During the FGD session, different framed discussion questions were raised to gain a detailed understanding of the perceived merits and drawbacks of improved stoves. Accordingly, most of them discussed that improved stoves are superior to traditional stoves. They did not choose to cook with traditional stoves.

---

**Figure 1** Likert-scale presentation of perceived health risk associated with household air pollution among pregnant women in the South Gondar Zone. Northwestern Ethiopia. ARI, acute respiratory infection.
...I can give my witness regarding the importance of an improved stove since I have been using it for some time now. It protects me from extreme heat and smoke. It also uses less fuel compared with the traditional ones. (25–31 years old, FGD 3) ... improved cook stove reduces the emission of smoke plus it uses less fuel than traditional ones. It also prevents the health problems like heart disease caused by smoke. (18–24 years old, FGD 1)

Some of the FGD discussants were familiar with using improved stoves made from mud before. In their discussion, they mentioned the benefits they have gained and most participants said they would like to use it if it is still available.

... we tried to build and use locally modified stoves even though they crumbled easily. We are eager to use improved cookstoves if they are available in our village. We don’t think using an improved cook stove is a luxury because it prevents health problems associated with using biomass fuels. (32–45 years old, FGD 1) ... I have been using improved stoves which I made from mud for the last nine years. I can cook both stewed and Injera at the same time. The fire is concealed inside the stove so it prevents the fire accident and uses less fuel. I have a heart condition I swear to GOD if I kept using traditional stoves I would be died by now. (32–45 years old, FGD 1)

The participants also discussed the barriers to using improved stoves in their homes. Availability and cost were frequently mentioned barriers to the installation and use of improved stoves in the study area.

... now it is over 200 Ethiopian birr which is unaffordable for farmers. (32–45 years old, FGD 2) ... we would love to use it if it was available here in our village. Because it uses less fuel and protects us from the harmful health effect caused by exposure to open fire and smoke. (32–45 years old, FGD 3) ... I think the barriers are unavailability and financial constraint. I heard that it was expensive even though I don’t know its exact price. (32–45 years old, FGD 3) ... we all are aware of the benefits of using improved cook stoves. if it was available, we would use it. Because nobody wants to cook under extreme heat and smoke. (25–31 years old, FGD 4)

Factors associated with health risk perception of kitchen smoke

A score for health risk perception of kitchen smoke was computed as the mean of the eight-item scores. Based on the normality test, our mean score data were a little skewed to the right (higher perception level) which cannot be assumed approximately normally distributed in terms of skewness and kurtosis. Shapiro-Wilk test (p>0.05) and visual inspection of their histogram, normal Q-Q plot and Box plot showed that the mean health risk perception score was not normally distributed with skewness of 0.031 (SE=0.119) and kurtosis of −0.592 (SE=0.237). Since the commonly used data transformations could not normalise its distribution, we analysed the dichotomised score as a dependent variable using logistic regression.

Hence, we classified respondents based on their responses into two categories: the not certainly agreed category (strongly disagreed/disagreed/neither agreed nor disagreed and the certainly agreed category (strongly
This was further dichotomised and coded as ‘0’ for not certainly agreed and ‘1’ for certainly agreed for positively worded statements. The resulting binary variable was analysed by logistic regression analysis. Associations were estimated by ORs with 95% CIs. The p value of 0.26 in the Hosmer-Lemeshow goodness-of-fit test confirms that the model is a good fit for our data.

Based on this study, 63% (95% CI 58 to 68%) of the participating pregnant women have perceived that HAP due to biomass fuel use causes various health problems. As shown in Table 2, the odds of having a high level of health risk perception were significantly associated with the 32–38 years age group as compared with their younger (18–24 years age) counterparts (OR 1.71, 95% CI 1.07 to 2.73), the rich category of the asset index than their comparators in the poor category (OR 2.12, 95% CI 1.32 to 3.41), presence of under-five children in the house (OR 1.92, 95% CI 1.26 to 2.91), being a member of any women group in their village (OR 1.92, 95% CI 1.29 to 2.85) and the probability of having a high level of health risk perception was 22% higher for a unit change in the family size of the household (OR 1.22, 95% CI 1.08 to 1.38). But, we did not find associations between health risk perception and the educational level of pregnant women and their husbands.

Factors associated with perceived benefits of improved stoves

The perceived benefit score was computed as the mean of the six-item scores. Similar to the health risk perception of HAP, the normality test of the data is a little skewed to the right (higher perceived benefit score). Shapiro-Wilk test (p>0.05) and visual inspection of their histogram, normal Q-Q plot and box plot showed that the mean perceived benefit score was not normally distributed with skewness of −0.244 (SE=0.119) and kurtosis of 0.157 (SE=0.237). Hence, we again analysed the dichotomised score as a dependent variable using logistic regression analysis. Similar classification was done as health risk perception of HAP and the resulting binary variable was analysed by logistic regression analysis and associations.

Accordingly, nearly three-fourth (74%) (95% CI 70% to 79%) of the participating pregnant women perceived that improved stoves had various benefits for their families. As shown in Table 3, the odds of having high perceived benefits of the improved stove were significantly associated with younger age group (18–24 years) as compared with their older (32–38 years age) counterparts (OR 1.94, 95% CI 1.07 to 3.53), presence of under-five children in the house (OR 1.72, 95% CI 1.08 to 2.74), primary and above husband educational level (OR 1.89, 95% CI 1.04 to 3.44), health risk perception of HAP (OR 2.61, 95% CI 1.49 to 4.58) and not happy with current stove (OR 1.69, 95% CI 1.10 to 2.57).

Table 2 Factors associated with health risk perception of household air pollution among pregnant women in the South Gondar Zone, Northwestern Ethiopia, 2022

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Perception</th>
<th>COR (95% CI)</th>
<th>P value</th>
<th>AOR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–24</td>
<td>46</td>
<td>38</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25–31</td>
<td>117</td>
<td>78</td>
<td>2.12 (1.21 to 3.73)</td>
<td>0.009</td>
<td>1.13 (0.81 to 1.57)</td>
</tr>
<tr>
<td>32–38</td>
<td>103</td>
<td>40</td>
<td>1.86 (1.39 to 2.50)</td>
<td>0.000</td>
<td>1.71 (1.07 to 2.73)</td>
</tr>
<tr>
<td>Asset index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>104</td>
<td>35</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>81</td>
<td>59</td>
<td>2.16 (1.30 to 3.60)</td>
<td>0.003</td>
<td>2.09 (1.31 to 3.341)</td>
</tr>
<tr>
<td>Rich</td>
<td>78</td>
<td>62</td>
<td>2.36 (1.42 to 3.92)</td>
<td>0.001</td>
<td>2.12 (1.32 to 3.41)</td>
</tr>
<tr>
<td>Member of women’s groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>100</td>
<td>89</td>
<td>2.20 (1.47 to 3.29)</td>
<td>0.000</td>
<td>1.92 (1.29 to 2.85)</td>
</tr>
<tr>
<td>No</td>
<td>166</td>
<td>67</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women educational status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unable to read and write</td>
<td>164</td>
<td>101</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read and write only</td>
<td>69</td>
<td>35</td>
<td>1.25 (0.71 to 2.19)</td>
<td>0.424</td>
<td>1.01 (0.59 to 1.7)</td>
</tr>
<tr>
<td>Primary and above</td>
<td>33</td>
<td>20</td>
<td>1.93 (1.11 to 3.34)</td>
<td>0.018</td>
<td>0.76 (0.44 to 1.30)</td>
</tr>
<tr>
<td>Presence of children in the house</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>135</td>
<td>82</td>
<td>1.93 (1.46 to 2.55)</td>
<td>0.000</td>
<td>1.92 (1.26 to 2.91)</td>
</tr>
<tr>
<td>No</td>
<td>131</td>
<td>74</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family size (4.75±1.61)</td>
<td>1.22 (1.08 to 1.38)</td>
<td>0.001</td>
<td>1.19 (1.05 to 1.34)</td>
<td>0.004</td>
<td></td>
</tr>
</tbody>
</table>

AOR, adjusted OR; COR, crude OR.
95% CI 1.03 to 2.78). But maternal age, drying fuel before use and houses without windows which were able to open were not significantly associated with the perceived benefits of improved stoves.

**DISCUSSION**

This study investigated cooking practices and perceived health risks of smoke from biomass fuel use and perceived benefits of improved stoves among pregnant women in rural Ethiopia. Data both from qualitative and quantitative approaches demonstrated that firewood and cow dung were identified as the dominant energy sources for cooking in mainly separated and semi-enclosed or enclosed kitchens in the study area. Similar biomass fuel use and cooking practices were reported in other studies. This finding could be explained by the fact that unprocessed biomass fuels including firewood and cow dung are the cheapest source of energy available and almost all rural women in LMICs rely on them to meet basic energy needs.

Seasonal variation in the type of biomass fuel was reported with firewood and agricultural residue commonly used during the dry season while firewood and cow dung was the main fuel mix during the rainy season. Our qualitative data also revealed that firewood and cow dung were the main energy sources with different mixes at different seasons of the year. A similar report from another study stated that households switched fuel sources between seasons due to practical factors of biomass fuel use. Evidence generated from the systematic review also reported that weather and season played a role in determining the dominant biomass fuel sources. It was also reported that fuel consumption varied seasonally and more consumption of solid biomass fuel was recorded in winter as compared with summer seasons. But, our result is contradicting other studies where the transition from the rainy to dry season did not alter cooking fuel types.

Both quantitative and qualitative data in this study indicated that the interviewed pregnant women have a relatively high health risk perception related to exposure
to HAP. This is in agreement with other qualitative studies that reported most participating women were familiar with the health effects of HAP from biomass fuel use. Similarly, a study in Rwanda showed that almost all of the respondents reported being concerned for their and their family’s health associated with HAP. Study participants in Kenya mentioned chest pain, sneezing, irritating eyes, breathing problems and congestion of the throat as health problems mainly due to HAP exposure.

One possible explanation for the relatively high level of health risk perception of HAP observed is that women are more concerned about indoor air pollution than men due to the social dimensions of women’s roles as also evidenced from other studies. Although we only studied women, the literature showed that gender is a dominant factor in the perceived risk as stated in similar findings from women in Finland and Estonia which confirmed women perceive general risks from wood smoke higher than men.

Another explanation for the higher health risk perception observed in this study may be that pregnant women are more concerned about environmental exposures during pregnancy because they are influenced by some personal, psychological and social factors. Evidence from previous studies also reported similar high-level health risk perceptions towards environmental exposure including HAP during pregnancy. Maternal exposure to biomass smoke during pregnancy has been suggested to be associated with increased risks of adverse birth outcomes such as preterm birth, low birth weight and small gestational age and intrauterine growth retardation.

In this study, women’s age, socioeconomic status, membership to any women’s group, presence of children in the house and family size were significantly associated with health risk perception for HAP from biomass fuel use. Thus, the health risk perception tends to be double in the age group of women aged 32–38 years. This result is similar to the findings of previous perception studies where women in the middle age group were more likely than younger respondents to score high levels of health risk perception of environmental hazards including HAP. But, literature suggested that the relationship between age and perception of HAP risk is U-shaped in that people under the age of 25 years are often not concerned with HAP risk, but people between the ages of 25 and 55 years have an increase in risk perception.

It was also observed that the odds of health risk perception are double among pregnant women with high levels of socioeconomic status as compared with their poor comparators. This is in alignment with the existing evidence demonstrating people with a relatively high monthly income had significantly increased degree of risk perception of air pollution. This is mainly because poverty inhibits getting information from various sources and create risks that may be disproportionately affecting women. In contradiction to our result, the wealth index was also statistically significant among those in lower (poor) categories of the wealth index.

The health risk perception of HAP was also nearly double among those who participated in any women group in their locality than non-participated women. This might be because as evidence suggests women’s groups are successful in achieving information sharing and awareness creation on different health agendas. Health risk perception levels were found to be significantly higher for those exposed to health-related information through different women groups.

Our result showed that women with under-five children in their house were twice more likely to have a high level of health risk perception of HAP as compared with women without under-five children in their house. This is aligned with other research findings where women with young children in their houses were perceived high health risk of HAP exposure and having one or more children was associated with a higher risk perception. The possible reason might be women are often concerned about the risks to their fetuses, infants, and children. But it is not always true as a contradicting result also reported on women with children in the household had lower odds of being concerned than those without children.

Family size is also significantly associated with women’s health risk perception of HAP. In our analysis, we found that the odds of having a high level of health risk perception were 19% higher for a unit increase in the family size. Previous research has also demonstrated that lower family size is negatively associated with levels of perceived risk. It might be due to more than one stove and prolonged cooking is common for large families’ cooking needs. Moreover, the size of the family also influenced the quantity of fuel used.

In this study, both quantitative and qualitative results revealed that almost all of the participating women perceived that improved stoves are useful. This is also reported in similar previous studies where almost all participating women believed that improved cooking stoves were superior to traditional stoves and had positive attitudes towards using improved stoves, especially on the reduction of the amount of wood used and time needed to cook food. Previous studies in Ethiopia have also reported similar results. The contradicted result was also reported in Rwanda where over half of the respondents had no prior awareness of improved stoves and in Uganda where most participants were unable to describe improved stoves.

In this study, an attempt was made to identify the factors associated with the perceived benefits of using improved stoves. As a result, it was found that younger women, the presence of under-five children at home, the education level of their husbands, unhappiness with the stove they are currently working on and higher awareness of the health risk of HAP were associated with their perceived benefits of improved stoves. The result is in agreement with other studies where increasing age was associated with decreased preference for improved stoves.
and younger women adopt improved stoves than their older counterparts.106 The possible justification might be younger women are more likely to understand new technologies and change their cooking behaviour more flexibly than older women who had greater intention to stick to traditional cooking technologies as reported by other previous studies.59 107 108 Perceived benefits of the improved stove are positively associated with education and perceptions of health risks of pollution.109 Results from previous studies link the perceived benefit and adoption of improved stoves with the educational level of household heads and family size.73 110

Although many pregnant women understand the dangers of biomass smoke and the benefits of improved stove use for themselves and their families, the availability and affordability of improved stoves were mentioned as major barriers to purchase and use. This evidence was supported by other studies where perceived health benefits, cheap prices and availability of improved stoves were found to be facilitators for the adoption of improved stoves.65 104 111 Since cooking has a locally specific culture, it is suggested that intervention efforts should take into account the sociocultural and other important issues to implement clean cooking solutions for the community.73 112

The reported high health risks perception of HAP and perceived benefit of improved stove in this study are promising for the effectiveness of future prevention efforts. The health risk perception of any hazards and perceived benefits of certain intervention are reported as key component of many health behaviour change theories.45 47 75 106 Consequently, any public health interventions aimed at reducing HAP in this setting in particular and in LMICs in general need to consider local culture including perception towards the health risk and benefits of intervention for effective adoption and use of interventional technologies as evidenced in previous studies.50 113

**Conclusion**

The traditional cooking method with biomass-fuelled stoves was a common practice indicating that households in the study area tend to be at the bottom of the energy ladder and often rely on fuel that is cheap and locally available but not very clean.

Participants perceived that HAP is associated with various health problems and improved stove intervention had benefits for their families. Eye irritation, and respiratory, cardiovascular and reproductive-related health problems were among the commonly mentioned health issues associated with kitchen smoke.

Since the keys to scaling up solutions for better household air quality lies in public risk perception of HAP on health and the perceived benefits from using improved stoves, this study revealed the likelihood of increasing the success of different local and national intervention programmes on HAP. This study also suggests that to successfully reduce HAP, clean cooking programmes and policies must consider many factors including cost and availability of improved stoves which can influence uptake and exclusive adoption and sustained use of proposed interventional stoves.

**Acknowledgements** The authors of this study would like to acknowledge the study participant pregnant women for their commitment to providing the required data. The authors would like to thank the field teams and local coordinators who worked thoroughly to collect the data. The authors also would like to give sincere gratitude to the South Gondar Zone health department and respective district health offices for their cooperation to commence this study.

**Contributors** HD was responsible in proposal writing, designing, recruitment, and training of supervisors and data collectors and analysis and write-up in all stages of the research project. AB and ST were responsible tostudy implementation, data collection, manuscript editing, supervision of the overall progression and final approval of the paper. All authors read and approved the final manuscriptsupervision

**Funding** This study was supported by Jimma and Debre Tabor universities.

**Map disclaimer** The inclusion of any map (including the depiction of any boundaries therein), or of any geographic or locational reference, does not imply the expression of any opinion whatsoever on the part of BMJ concerning the legal status of any country, territory, jurisdiction or area or of its authorities. Any such expression remains solely that of the relevant source and is not endorsed by BMJ. Maps are provided without any warranty of any kind, either express or implied.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** This study was approved by the institutional review boards of the Jimma University with ethical clearance provided (ref no: HRPGD/538/2021) to conduct the study. All participants were asked to give consent for participation and audio recording before the commencing after explaining the objectives and importance of the study. Official letters of cooperation were given to South Gondar Zone health department and respective district health offices and permission to conduct the study was obtained. The right of the respondent to withdraw from the interview or not to participate was respected. The information provided by the respondents were not used for other purpose other than to the stated objectives. The potential benefits of involving in this research was explained to the study participants. Participants gave informed consent to participate in the study before taking part.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available on reasonable request. Data are available on reasonable request. Extra data are available from the corresponding author on reasonable request.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

**ORCID iD**

Demelash Habtamu http://orcid.org/0000-0002-9381-2184

**REFERENCES**

1. Amegah AK, Quansah R, Jaakkola JJK. Household air pollution from solid fuel use and risk of adverse pregnancy outcomes: a


11. Recommendation P. *STROBE* statement-checklist of items that should be included in reports of cross-sectional studies. 2013.


52. Steinmayak S. Cooking up change in the Himalayas: experimental evidence on Cookstove promotion. Duke environmental and energy economics working paper series EE 2016;16.


