RESEARCH ARTICLE

REVISED Cooking with biomass fuel and cardiovascular disease: a cross-sectional study among rural villagers in Phitsanulok, Thailand [version 2; peer review: 2 approved, 1 approved with reservations]

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v2 **First published:** 29 Apr 2020, **9**:307
https://doi.org/10.12688/f1000research.23457.1
Latest published: 08 Oct 2020, **9**:307
https://doi.org/10.12688/f1000research.23457.2

Abstract

Background: Burning biomass fuel is a major source of indoor air pollution; about 40% of Thai people still use biomass for cooking. There is increasing evidence of the association between biomass smoke exposure and serious health effects including cardiovascular disease. The object of this cross-sectional study was to investigate the association between biomass use for household cooking and cardiovascular outcome, including coronary heart disease, hypertension, high cholesterol, diabetes mellitus, and stroke among rural villagers in Phitsanulok, Thailand.
Methods: Data from 1078 households were collected using a face-to-face interview questionnaire. In each household, data on cardiovascular disease, cooking practices, and cooking fuel, types of fuel they normally used for cooking, were collected.
Results: After being adjusted for gender, age, cigarette smoke, secondhand smoke, and exposure to other sources of air pollution, it was found that the family members of cooks using biomass fuel were at risk of coronary heart disease (CHD; OR=4.35; 95%CI 0.10–18.97), hypertension (OR=1.61; 95%CI 1.10–2.35), high cholesterol (HC; OR=2.74; 95%CI 1.66–4.53), and diabetes (OR=1.88; 95%CI 1.03–3.46). Compared to LPG use, using wood was associated with stroke (OR=7.64; 95%CI 1.18–49.61), and using charcoal was associated with HC (OR=1.52; 95%CI 1.04–2.24). Compared to never user, household cooks who sometimes use charcoal had an increased risk of hypertension (OR=2.04; 95%CI 1.32–3.15), HC (OR=2.61; 95%CI 1.63–4.18), and diabetes (OR=2.09; 95%CI 1.17–3.73); and cooks who often use charcoal had an elevated risk of stroke (OR=3.17; 95%CI 1.04–9.71), and HC (OR=1.52; 95%CI 1.02–2.27) to their family members.
Conclusions: The study results were consistent with those found in

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	1	**2**	**3**
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version 1 29 Apr 2020	✓ report	? report	

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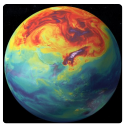
studies from other parts of the world, and supports that exposure to biomass smoke increase cardiovascular diseases. The issue should receive more attention, and promotion of clean fuel use is a prominent action.

Keywords
Biomass fuel, cardiovascular diseases, household air pollution, kitchen smoke, cooking fume



This article is included in the Climate Action gateway.

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Author roles: Juntarawijit C: Conceptualization, Formal Analysis, Investigation, Methodology, Project Administration, Supervision, Writing – Original Draft Preparation; **Juntarawijit Y**: Conceptualization, Investigation, Methodology, Project Administration, Validation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This study was supported by Naresuan University, grant No. R2560C118.
The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

How to cite this article: Juntarawijit C and Juntarawijit Y. **Cooking with biomass fuel and cardiovascular disease: a cross-sectional study among rural villagers in Phitsanulok, Thailand [version 2; peer review: 2 approved, 1 approved with reservations]** F1000Research 2020, **9**:307 https://doi.org/10.12688/f1000research.23457.2

First published: 29 Apr 2020, **9**:307 https://doi.org/10.12688/f1000research.23457.1

REVISED **Amendments from Version 1**

In this version, the term cooking fuel and cooking smoke was clarified. In statistical analysis, more information was added and the regression model use was precisely described.

Any further responses from the reviewers can be found at the end of the article

Introduction

Cooking smoke is a major source of household air pollution, which affects billions of people around the world, especially in developing countries. Globally, nearly 3 billion people still use solid fuels (wood, charcoal, crop residues, and dung) for cooking and heating[1]. Smoke from wood burning contains a large number of pollutants, including particulate matter, carbon monoxide, nitrogen dioxide, formaldehyde, and a number of highly toxic organic compounds, such as benzene, 1, 3 butadiene, benzo[a]pyrene and other toxic polycyclic aromatic hydrocarbons[2]. In addition to fuel burning smoke, overheated of cooking oils might also produce smoke which depended on several factors, including cooking oils, cooking methods, cooking equipment, and food types[3].

The use of solid fuel for cooking and/or household energy sources increases respiratory and non-respiratory illnesses in both adults and children. Those effects that are well established are acute respiratory infections, chronic obstructive pulmonary disease (COPD), lung cancer, asthma, tuberculosis, and cataracts[4,5]. In children, biomass use is related to mortality, and acute lower respiratory tract infections, and some other non-respiratory illness, such as poor lung function, low birthweight, nutritionaldeficiency, and impairment of learning ability[6,7].

Though with limited evidence, recent studies linked biomass smoke exposure and cardiovascular diseases (CVD), e.g. coronary heart disease (CHD), hypertension, diabetes, and stroke[8–11]. In laboratory studies, chronic exposure to biomass smoke increased the thickness and plaque of blood vessels[12]. In epidemiological studies, Peruvians who live in high altitude environments and use biomass fuel had an elevated prevalence of hypertension[13]. A study among villager women in Bangladesh reported an association between elevated cumulative exposure to biomass smoke and the prevalence of hypertension[14]. A similar result was found in a study in Shanghai Putuo, which found using solid fuel increases the risk of hypertension, CHD, and diabetes[15]; and a study in Shanxi, China reported an increased risk of hypertension, CHD, stroke, diabetes, and dyslipidemia[16]. A recent study by Yu *et al.*[17] also linked solid fuel use to cardiovascular mortality.

On a global scale, CVD is the number one cause of death and is responsible for about 18 million deaths annually[18]. In Thailand, CVD accounts for 23% of the national mortality[19]. Currently, there is no study on the effect of biomass smoke on CVD in Thailand. It was reported that about 40% of Thai households still use biomass, mainly charcoal, wood, and agriculture residue, for cooking[20]. The objective of this study is to investigate a possible association between biomass use for cooking and cardiovascular diseases, including CHD, hypertension, HC, diabetes, and stroke. The study uses data from a cross-sectional survey among rural villagers in Phitsanulok, Thailand. The result could be used for disease prevention and control, and to support the global literature.

Methods

Study design and setting

This is cross-sectional study. Participants are rural villagers living in Phitsanulok Province, Thailand. Phitsanulok is a midsize province located about 400 km north of Bangkok. There are 866,891 people in the area of 9 districts. Most of the people are rice farmers[21].

Study participants and sampling procedure

Participants were randomly selected using multistage sampling. Out of the 9 districts in Phitsanulok province, 5 were randomly selected. In each district, one sub-district and a local health-promoting hospital were approached. In each sub-district with support from the local health-promoting hospital, a total of 1,150 households were approached and 1,134 (98.6%) people agreed to participate in the study. In each household, only one participant who was responsible for household cooking and aged over 20 years was selected. After data cleanup, 56 (4.9%) items of data were missing important information, such as age, gender, cooking practice. The final data from 1,078 people were used for statistical analysis.

The minimum sample size was calculated to be 1,034, using unmatched cross-sectional study with the following assumptions:two-sided significance level = 95%; power of detection = 80%; percent unexposed with outcome = 5%; and odds ratio = 2.0.

Study questionnaire

Data was collected using a face-to-face interview questionnaire, which was administered by 15 village health volunteers (provided as *Extended data* in English[22]). The interviews took place in the house of participants. The data was collected during the period of May–June 2017. Health volunteers were all trained on how to properly carry out the interview and use the questionnaire. The questionnaire was designed to collect information on demographic data, fuel use for cooking, and other cooking practices. In addition to general demographic data, participants were also asked a history of tobacco use (ever, never), and working in factory environments using “yes” or “no” questions. Ever smoker referred to those who smoke more than 100 cigarettes in their lifetime. Data on pesticide use was also measured by “yes” or “no” questions: “Have you ever spray or mix pesticide?”. For cooking fuel data, we asked about the types of fuel they used for cooking food (wood, charcoal, LPG, electricity), and the frequency of using each types of fuel. Data collected on cooking practices were types of cooking oil, the frequency of tears while cooking (TWC) (never, sometimes, often), kitchen location (inside a house, outside a house, both inside and outside a house), and the characteristics of kitchen ventilation (good or poor ventilation).

The presence of cardiovascular disease was determined by the participant response to the question: "Have you ever been diagnosed with the following diseases (coronary heart disease (CHD), hypertension, high cholesterol (HC), diabetes mellitus, stroke) by a medical doctor?". For diseases among their family members, we asked "Did you have a family member with the following diseases?".

The content validity of the questions was tested by three experts, and the Index of Item Objective Congruence (IOC) was between 0.7–1.0. The questionnaire was also tested for question sequencing and understanding using a group of 30 people with a similar background to the intended participants.

Statistical analysis

Demographic and prevalence of cardiovascular disease were descriptively analyzed. Comparison between groups were analyzed using chi-square test for categorical variables, and independent t-test for continuous variables. The association between cardiovascular disease was analyzed using binary multiple logistic regression with odds ratios (OR) and 95 percent confidence interval (CI) adjusted for gender (male, female), age (continuous data), cigarette smoking (ever, never), living smoker (yes, no), working with smokers (yes, no), and exposure to air pollution (yes, no). These adjusted variables of the repondents were used also when analysis for ORs of disease risk among the respondents' family members. All statistical analyses were performed using IBM SPSS version 19 and OpenEpi (online version 3.01). Statistical significance was set at a p-value of less than 0.05.

Ethical considerations

The study was approved by the Ethical Committee of Naresuan University (COA No. 485/2016), and written informed consent from the respondents was obtained before the interviews were conducted.

Results

Most of the respondents were women (84.2%) with a mean age of 53.04 ± 12.93 yr. The highest education levels were primary school or high school. Most were farmers (36.0%) and 20.2% were causal workers on farms. About 10% were smokers and 33% lived with a smoker. Additional information on the demographic data is shown in Table 1 and in *Underlying data*[23].

About 70% of the respondents reported using biomass for cooking (Table 2). However, when asked for fuel types that they usually use for cooking, 64.5% reported LPG and 32.3% charcoal. Among those who use charcoal, 38.6% use it often. About half have a kitchen located inside a house with good ventilation. Almost all reported having TWC either sometimes or often. Most of them cook every day.

The study found hypertension, HC, and diabetes to be the most common cardiovascular outcomes (Table 3). Compared to non-user group, biomass users had a significantly higher prevalence of hypertension, and HC, and their family members also had more incidence of hypertension, HC, diabetes, and heart disease.

Table 1. Demographic data.

Characteristics (N=1078)	N (%)
Gender	
Male	170 (15.8)
Female	908 (84.2)
Age (yr.)	
20–30	67 (6.2)
31–40	136 (12.6)
41–50	205 (19.0)
51–60	343 (31.8)
61–70	258 (23.9)
71–80	69 (6.4)
Mean = 53.04 ± 12.93 (Age range 20–80 yr.)	
Education completed	
Primary school	757 (71.9)
Secondary school	246 (23.4)
College diploma	50 (4.8)
Missing	25 (2.3)
Occupation	
Farmer	388 (36.0)
Grocer	89 (8.3)
Private or government employee	57 (5.3)
Causal worker	218 (20.2)
Housewife	223 (20.7)
Other/unemployed	103 (9.6)
Cigarette smoking	
Ever smoke	111 (10.3)
Never smoke	967 (89.7)
Living with smokers	
Yes	362 (33.8)
No	710 (66.2)
Missing	6 (0.6)
Working with smokers	
Yes	172 (16.1)
No	895 (83.9)
Working in a factory	
Yes	175 (16.4)
No	894 (83.6)
Missing	9 (0.8)
Spray or mix pesticides	
Yes	425 (39.5)
No	651 (60.5)

Characteristics (N=1078)	N (%)
Missing	4 (0.4)
Fuel use for cooking	
Wood	27 (2.5)
Charcoal	348 (32.3)
LPG	695 (64.5)
Electricity	8 (0.7)
Frequency of using charcoal	
Never	495 (46.4)
1–2 times per week	160 (15.0)
3 times per week or more	411 (38.6)
Kitchen location	
Inside a house	570 (53.4)
Both inside and outside	134 (12.6)
Outside a house	363 (34.0)
Tears while cooking	
Often	49 (4.6)
Sometimes	537 (50.8)
Never	472 (44.6)
Missing	20 (1.9)
Cooking frequency	
Everyday	984 (91.3)
Somedays	94 (8.7)
Using charcoal duration (year)	
Not use	502 (46.6)
1–20	146 (13.6)
21 or more	429 (39.8)

Further analysis using logistic regression and control variables, revealed that compared to gas users, biomass users had family members with elevated CHD, hypertension, HC, and diabetes (Table 4). Among different types of fuel, household cooks using wood had a significant elevated risk of CHD (OR=7.64, 95%CI 1.18-49.61), and their family members had an elevated risk of HC (OR=1.52, 95%CI 1.04-2.24). Comparing frequency of charcoal use, those who use charcoal sometimes or often are more likely to have CHD, hypertension, HC, and diabetes as compared to those who never use charcoal. The family members of charcoal users also had a significant increase of HC and stroke. When using TWC as an indicator for smoke exposure, it was found that those who always had TWC had significantly increased risk of stroke (OR=2.16;

Table 2. Demographic data among biomass and LPG users.

Characteristics	Biomass, n (%)	LPG, n (%)	P–value*
Gender			
Male	114 (15.1)	56 (17.4)	0.341
Female	642 (84.9)	266 (82.6)	
Age			
20–30	34 (4.5)	33 (10.2)	<0.001**
31–40	89 (11.8)	47 (14.6)	
41–50	132 (17.5)	73 (22.7)	
51–60	249 (32.9)	94 (29.2)	
61–70	204 (27.0)	54 (16.8)	
71–80	48 (6.3)	21 (6.5)	
Education completed			<0.001**
Primary school	569 (76.9)	188 (60.1)	
Secondary school	142 (19.2)	104 (33.2)	
College diploma or higher	29 (3.9)	21 (6.7)	
Missing	16 (2.1)	9 (2.8)	
Occupation			<0.001**
Farmer	299 (39.6)	89 (27.6)	
Grocer	54 (7.1)	35 (10.9)	
Private or government employee	36 (4.8)	21 (6.5)	
Causal worker	130 (17.2)	88 (27.3)	
Housewife	161 (21.3)	62 (19.3)	
other	76 (10.1)	27 (8.4)	
Cigarette smoking			0.490
Ever smoke	81 (10.7)	30 (9.3)	
Never smoke	675 (89.3)	292 (90.7)	
Living with smokers			0.475
Yes	259 (34.4)	103 (32.2)	
No	493 (65.6)	217 (67.8)	
Missing	4 (0.5)	2 (0.6)	
Working with smokers			**0.054**
Yes	131 (17.5)	41 (12.8)	
No	616 (82.5)	279 (87.2)	
Missing	9 (1.2)	2 (0.6)	

Characteristics	Biomass, n (%)	LPG, n (%)	P–value*
Working in a factory			**0.077**
Yes	113 (15.1)	62 (19.4)	
No	637 (84.9)	257 (80.6)	
Missing	6 (0.8)	3 (0.9)	
Using pesticides			**0.001****
Yes	321 (42.6)	104 (32.3)	
No	433 (57.4)	218 (67.7)	
Missing	2 (0.3)		
Kitchen location			**<0.001****
Inside a house	364 (48.6)	206 (64.8)	
Both inside and outside	109 (14.6)	25 (7.9)	
Outside a house	276 (36.8)	87 (27.4)	
Kitchen ventilation			0.580
Good	504 (96.9)	247 (97.6)	
Poor	16 (3.1)	6 (2.4)	
Cooking frequency			0.035**
Everyday	699 (92.5)	285 (88.5)	
Someday	57 (7.5)	37 (11.5)	

* P–value of chi square test for difference between biomass user and not use group, 2–tailed test

** Significantly difference, p <0.05

95%CI 1.08-4.32), and those with sometimes TWC had a CHD risk (OR=2.64; 95%CI 1.02-6.81). Regarding kitchen location, the family members of cooks having kitchens both inside and outside a house had an elevated risk of stroke (OR=4.60; 95%CI 1.14-18.54).

Discussion

This study presented an association between cardiovascular diseases and exposure to smoke from biomass, mainly charcoal, which is relatively cleaner when compared to wood, coal, or dung, a biomass which were often found in the literature. The study also showed that biomass use not only affects household cooks but also their family members. It was found that biomass users have a higher prevalence of hypertension and HC, and their family members had a higher prevalence of hypertension, HC, diabetes, and CHD (Table 3). Further analysis using logistic regression and control for potential confounder showed a significant OR of biomass use and CHD(F), hypertension(F), HC(F), and diabetes(F) (Table 4). Compared to LPG, wood use also had a strong association with stroke (OR=7.64; 95%CI 1.18–49.61). Among charcoal users, those who use it sometimes or often had an elevated risk of CHD, hypertension, HC, and diabetes for themselves, and risk of HC and stroke for their family members. The results are consistent with the literature. Previous research found biomass smoke contains a lot of pollutants, especially fine particulates, and carbon monoxide which are known to cause cardiovascular effects[2]. In laboratory studies, biomass smoke exposure was associated with endothelial inflammation[24].

For hypertension, we found both cooks and their family members have a higher prevalence of hypertension (Table 3).

Table 3. Prevalence of cardiovascular diseases among biomass and LPG users.

Disease	Biomass, n/total n (%)	LPG, n/total n (%)	p–value*
Hypertension(R)[a]	214/750 (28.5)	66/321 (20.6)	0.007**
Hypertension(F)[b]	152/729 (21.0)	44/305 (14.4)	0.014**
High cholesterol, HC(R)	166/748 (22.2)	48/320 (15.0)	0.007**
High cholesterol, HC(F)	120/729 (16.5)	21/305 (6.9)	<0.001**
Diabetes(R)	91/751 (12.1)	30/321 (9.3)	0.189
Diabetes (F)	62/729 (8.5)	14/305 (4.6)	0.028**
Coronary heart disease, CHD(R)	20/749 (2.7)	6/321 (1.9)	0.521
Coronary heart disease, CHD(F)	20/728 (2.7)	2/304 (0.7)	0.034**
Stroke(R)	10/750 (1.3)	3/321 (0.9)	0.585
Stroke (F)	16/729 (2.2)	3/305 (1.0)	0.186

[a] disease of respondent (R)

[b] disease of respondent's family member (F)

* P–value of chi square test for difference between diseases prevalence among biomass use and LPG use

** Significant at P < 0.05, 2-tailed test

Table 4. Association (OR)* between biomass use and cardiovascular outcomes.

	Hypertension(R)	(F)	HC(R)	HC(F)	Diabetes(R)	Diabetes(F)	CHD(R)	CHD(F)	Stroke(R)	Stroke (F)
Biomass use										
Yes	1.27 (0.91–1.77)	**1.61 (1.10–2.35)**	1.28 (0.88–1.86)	**2.74 (1.66–4.53)**	1.08 (0.69–1.70)	**1.88 (1.03–3.46)**	1.18 (0.46–3.02)	4.35 (0.10–18.97	1.27 (0.33–4.87)	4.45 (0.97–20.56)
No	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fuel type										
Wood	1.11 (0.45–2.74)	1.93 (0.77–4.85)	1.31 (0.51–3.36)	1.45 (0.47–4.41)	0.58 (0.13–2.59)	2.11 (0.59–7.48)	1.63 (0.19–13.66)	NA	**7.64 (1.18–49.61)**	0.72 (0.27–1.96)
Charcoal	0.79 (0.57–1.09)	1.22 (0.86–1.72)	0.89 (0.63–1.26)	**1.52 (1.04–2.24)**	0.97 (0.63–1.48)	1.47 (0.89–2.43)	1.14 (0.49–2.65)	1.54 (0.64–3.73))	2.03 (0.58–7.09)	0.93 (0.68–1.26)
LPG/Electric	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Charcoal use										
Often	1.10 (0.79–1.52)	1.10 (0.77–1.57)	1.30 (0.90–1.87)	**1.52 (1.02–2.27)**	1.44 (0.92–2.26)	1.56 (0.94–2.61)	1.33 (0.51–3.48)	1.37 (0.52–3.63)	1.66 (0.44–6.29)	**3.17 (1.04–9.71)**
Sometimes	**2.04 (1.32–3.15)**	1.28 (0.80–2.04)	**2.61 (1.63–4.18**)	1.11(0.63–1.96)	**2.09 (1.17–3.73)**	0.69 (0.29–1.61)	**4.11 (1.40–12.11)**	1.50 (0.44–5.18)	2.76 (0.56–13.50)	0.59 (0.07–5.21)
Never	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tears while cooking										
Often	0.84 (0.41–1.73)	0.71 (0.31–1.65)	0.56 (0.23–1.35)	0.76 (0.29–2.01)	0.93 (0.34–2.55)	0.23 (0.03–1.75)	3.45 (0.66–17.94)	1.07 (0.13–8.78)	**2.16 (1.08–4.32)**	1.80 (0.96–3.35)
Sometimes	0.82 (0.61–1.11)	0.96 (0.69–1.34)	0.92 (0.66–1.28)	1.02 (0.70–1.49)	1.17 (0.78–1.77)	0.80 (0.49–1.29)	**2.64 (1.02–6.81)**	1.13 (0.47–2.73)	0.98 (0.69–1.41)	1.04 (0.78–1.40)
Rarely	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Kitchen location										
Inside	0.80 (0.58–1.11)	0.94 (0.67–1.34)	1.11 (0.78–1.58)	1.07 (0.72–1.60)	0.83 (0.54–1.27)	0.71 (0.42–1.18)	2.14 (0.77–5.92)	2.11 (0.75–5.93)	1.89 (0.45–7.89)	1.87 (0.55–6.33)
Both	1.00 (0.61–1.64)	1.08 (0.64–1.83)	0.85 (0.48–1.51)	0.84 (0.44–1.61)	1.17 (0.62–2.20)	0.76 (0.35–1.65)	1.96 (0.45–8.55)	0.50 (0.06–4.36)	4.62 (0.81–26.47)	**4.60 (1.14–18.54)**
Outside	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

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	Hypertension(R)	(F)	HC(R)	HC(F)	Diabetes(R)	Diabetes(F)	CHD(R)	CHD(F)	Stroke(R)	Stroke (F)
Charcoal use										
Often	1.10 (0.79–1.52)	1.10 (0.77–1.57)	1.30 (0.90–1.87)	**1.52 (1.02–2.27)**	1.44 (0.92–2.26)	1.56 (0.94–2.61)	1.33 (0.51–3.48)	1.37 (0.52–3.63)	1.66 (0.44–6.29)	**3.17 (1.04–9.71)**
Sometimes	**2.04 (1.32–3.15)**	1.28 (0.80–2.04)	**2.61 (1.63–4.18**)	1.11(0.63–1.96)	**2.09 (1.17–3.73)**	0.69 (0.29–1.61)	**4.11 (1.40–12.11)**	1.50 (0.44–5.18)	2.76 (0.56–13.50)	0.59 (0.07–5.21)
Never	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Using charcoal location										
Inside	0.95 (0.62–1.45)	0.89 (0.56–1.42)	1.26 (0.81–1.96)	1.40 (0.84–2.34)	0.72 (0.41–1.26)	0.83 (0.41–1.66)	2.13 (0.75–6.09)	**4.71 (1.36–16.32)**	1.32 (0.27–6.42)	2.46 (0.67–9.01)
Both	2.03 (0.89–4.63)	0.64 (0.21–1.92)	1.32 (0.54–3.25)	1.18 (0.38–3.64)	1.19 (0.42–3.38)	0.84 (0.19–3.78)	1.46 (0.16–13.01)	2.83 (0.30–27.07)	3.35 (0.24–47.21)	2.19 (0.22–21.51)
Outside	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Using charcoal duration (year)										
>20	**1.38 (1.01–1.89)**	1.05 (0.74–1.50)	**1.73 (1.22–2.44)**	1.34 (0.89–2.01)	1.50 (0.98–2.30)	1.55 (0.93–2.57)	1.36 (0.99–1.87)	1.49 (0.60–3.74)	2.39 (0.70–8.24)	1.63 (0.51–5.19)
1–20	1.28 (0.78–2.12)	1.40 (0.87–2.25)	1.25 (0.70–2.22)	1.54 (0.89–2.68)	1.31 (0.65–2.63)	0.55 (0.21–1.46)	1.28 (0.77–2.11)	0.71 (0.15–3.46)	NA	2.62 (0.75–9.16)
Not use	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Years of using charcoal o	1.003 (0.996–1.010)	1.003 (0.995–1.011)	**1.010 (1.002–1.017)**	1.007 (0.998–1.016)	1.004 (0.995–1.013)	**1.013 (1.001–1.024)**	1.015 (0.997–1.034)	1.012 (0.990–1.033)	1.014 (0.989–1.039)	1.011 (0.986–1.037)

*Logistic regression, adjusted for gender (male, female), age (continuous), cigarette smoking (ever, never), living with smoker (yes, no), working with smoker (yes, no), pesticide use (yes, no), working in a factory (yes, no)

Significant value ($p<0.05$) is given in bold letters

F1000Research 2020, 9:307 Last updated: 05 NOV 2020

Further analysis indicated an elevated risk of hypertension (OR=1.61; 95%CI 1.10–2.35) among family members of cooks using biomass for cooking (Table 4). As compared to those who never use it, cooks who sometimes use charcoal have twice the risk of hypertension (OR=2.04; 95%CI 1.32–3.15) and those who use charcoal over twenty years have 1.38 times the risk of hypertension (OR=1.38; 95%CI 1.01–1.89). In the literature, there is increasing evidence to link biomass smoke and hypertension[25,26]. A study in Peru found that biomass users had an increased risk of both prehypertension (OR=5.0; 95%CI 2.6–9.9), and hypertension (OR=3.5; 95%CI 1.7–7.0)[13]. In Bangladesh, it was found that among rural women, one additional year of biomass smoke exposure to increase risk of hypertension by 61% (OR=1.61; 95%CI 1.16–2.22)[14]. Recent studies in Honduras also linked PM2.5 and black carbon exposure and hypertension among women using traditional and improved stoves[26].

The current study also found a higher prevalence of HC among cooks and their family members using biomass fuel (Table 3) with a significant OR of 2.74 (95%CI 1.66–4.53) for family members (Table 4). The result showed a difference in the risk of HC among those who use wood, charcoal, and LPG. This risk also varied particularly according to the frequency of charcoal use. Compared to nonusers, an elevated risk of HC was found among cooks who sometimes use charcoal (OR=2.04; 95%CI 1.32–3.15), and among those who use charcoal over 20 years (OR=1.73; 95%CI 1.22–2.44). Among cooks, every year of using charcoal will increase risk of HC by about 1% (OR=1.010; 95%CI 1.002–1.017). Risk of HC was also increased among family members of cooks who often use charcoal (OR=1.52; 95%CI 1.02–2.27). Though the evidence was limited, other studies have found an association between cholesterol and COPD, a disease often found among biomass users[3]. A study in Ghana also found a strong association between wood smoke exposure and several hematological and biochemical indices, including HC (OR=20.44; 95%CI 2.610–160.2)[27]. The higher OR might be explained by the difference in biomass types, which was found to be wood in other studies, while most of respondents in this study use charcoal which is relatively cleaner.

We found about 10% of the respondents had type 2 diabetes and the prevalence of the disease was higher among biomass users (Table 3). Logistic regression analysis revealed a significant risk of diabetes among cooks using charcoal sometimes (OR=2.09; 95%CI 1.17–3.73) as compared to the never user group (Table 4). Among family members of cooks, risk of diabetes was elevated by using biomass fuel (OR=1.88; 95%CI 1.03–3.46), and years of using charcoal (OR=1.013; 95%CI 1.001–1.024). Similar results have also been reported by several studies on the effect of particulate matter or traffic-related air pollutants on diabetes[28]. In addition, experimental studies may provide potential mechanisms, including glucose homeostasis, systemic inflammation, stress in the liver and endoplasmic reticulum, and alterations of mitochondrial and other adipose tissue[29]. Currently, epidemiological studies on the effect of indoor air pollution on diabetes are rare. A study of women in Honduras reported an association between the prevalence of prediabetes/diabetes and PM2.5 in kitchen biomass cooking stoves[30]. This was consistent with the results from a previous study from Shanghai Putuo, which also found an elevated risk of several cardiovascular diseases including diabetes (OR=2.48; 95%CI 1.59–3.86) among people using solid fuel at home[15].

Those who use biomass for cooking had a risk of CHD 4.35 times (95%CI 0.10–18.97) of LPG users; and those using charcoal sometimes had risk of CHD 4.11 times (95%CI 1.40–12.11) of never user group. These results are consistent with evidence from cigarette smoke and ambient air pollution. In animal studies, biomass fuel smoke caused arteriosclerotic effects in animal blood vessels[12]. Studies found COPD as a risk factor of CHD[31]; and our previous study found elevated chronic symptoms, such as chronic cough, dyspnea and runny nose which is a sign of COPD among cooks using biomass fuel for cooking[3]. Epidemiological studies also reported an association between solid fuel smoke exposure and CHD[32]. A study in Pakistan found that rural women who currently use solid fuel had an increased risk of acute coronary syndrome (OR=4.8; 95%CI 1.5–14.8)[33]. This is consistent with a study from Shanghai Putuo, which found solid fuel use in the home is associated with CHD (OR=2.58; 95%CI 1.53–4.32)[15], and study from Shanxi, China found an elevated risk of CHD (OR=2.25) among solid fuel users[16].

In this study, respondents who use wood (OR=7.64; 95%CI 1.18–49.61) and charcoal (OR=2.03; 95%CI 0.58–7.09) had an elevated risk of stroke as compared to clean fuel users (Table 4). Among charcoal users, those using charcoal sometimes (OR=1.66; 95%CI 0.44–6.29) and often (OR=2.76; 95%CI 0.56–13.50) seem to have a higher risk of stroke but a significant elevation was found only among the family members of cooks using charcoal often (OR=3.17; 95%CI 1.04–9.71). This was consistent with the literature. The association between household solid fuel use and stoke were also reported in a study from Shanghai Putuo (OR=1.87; 95% CI 1.03–3.38)[15], and study from Shanxi, China (OR=1.64)[16]. In ambient settings, a long-term effect of PM exposure on cardiovascular disease, including stroke, was well established[34]. It was estimated that for each 10 $\mu g/m^3$ increment in PM10, risk of overall stroke events will increase by 1.06 times (95%CI 1.02–1.11), and the risk of stoke mortality by 1.08 times (95%CI 0.99–1.18)[35].

One potential drawback of this study was the use of self-reported data of diseases. Without the confirmation of medical records, the survey diseases are subjected to information bias. However, the bias will be distributed equally to all comparison groups, and this tends to underestimate the result. The number of participants included in this study was also rather small to detect the actual association of a rare disease, e.g. stroke. By using cross-sectional design, the study result cannot explain the causal relationship, because it is not known whether exposure or the disease occurred first. However, the problem is minimal for rare diseases.

Conclusions

The results from this study support research findings in other part of the world that using biomass for cooking increases the risk of cardiovascular diseases. This study also confirms the negative effects of using charcoal, which is considered to be a relatively cleaner fuel as compared with wood, dung, coal, and other agricultural residues. Concerned organizations should pay more attention to the issue and promote clean fuel usage.

Data availability

Underlying data

Figshare: Household cooking and cardiovascular diseases, https://doi.org/10.6084/m9.figshare.12117066.v2[23].

This project contains the following underlying data:

- Household cooking and cardiovascular diseases.sav (Collected demographic and cardiovascular diseases data)
- Data dictionary.docx (Word document containing dictionary for study dataset)

Extended data

Figshare: Questionnaire-household cooking and cardiovascular disease, https://doi.org/10.6084/m9.figshare.12121887.v2[22].

This project contains the following extended data:

- Questionnaire-household cooking and cardiovascular disease.docx (Study questionnaire in English)
- Questionnaire-household cooking and cardiovascular disease-Thai.docx (Study questionnaire in Thai)

Acknowledgements

We would like to thank the participants in this study. Our appreciation also goes to local health promoting hospitals in Phitsanulok and the village health volunteers for data collection. We would like also to thank Mr. Kevin Mark Roebl of the Division of International Affairs and Language Development, Naresuan University for editing assistance.

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Open Peer Review

Current Peer Review Status: ✔ ✔ ?

Version 2

Reviewer Report 05 November 2020

https://doi.org/10.5256/f1000research.29890.r72717

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Ogonna N.O. Nwankwo
Department of Community Medicine, University of Calabar Teaching Hospital, Calabar, Nigeria

First off, thank you for setting out to provide more evidence on this important public health issue that affects a large proportion of people globally.
I will categorize my comments under major and minor issues with the manuscripts that I believe should be worked on.

Major issues:

I believe there is a need for reanalysis of the data based on the issue I have raised in the result section concerning the definition of the biomass use which is a major variable of interest for this study i.e. classification of participants into biomass users and non-biomass users. This may probably result in a significant change in the results outputs, discussion and conclusion of your study.

Minor issues:

I am going to make my feedback based on the structure of the manuscript. Some of my comments have been made by the other peer reviewers but seems to have been missed in this most current version.

Abstract:

- In the abstract, it may be good to write in full LPG. I believe it is best to use standardized abbreviations. I am not sure that HC is a widely used abbreviation?
- *"The **object** of this cross-sectional study was ....."*
  Do you mean "The **objective** of this cross-sectional study was ....."?
- *"In each household, data on cardiovascular disease, cooking practices, and cooking fuel, types of*

fuel they normally used for cooking, were collected."
Can be better phrased as: "In each household, data on cardiovascular disease, cooking practices, cooking fuel and types of fuel they normally used for cooking were collected."

- *"...and supports that exposure to biomass smoke increase cardiovascular diseases."*

Do you mean "...and supports that exposure to biomass smoke **increases the risk of** cardiovascular diseases."?

Introduction:

- "*In addition to fuel burning smoke, overheated of cooking oils might also produce smoke which depended on several factors, including cooking oils, cooking methods, cooking equipment, and food types3"*

This sentence needs to be rephrased to ensure better clarity.

- *"non-respiratory illness, such as poor lung function, low birthweight,**nutritionaldeficiency**, and impairment of learning ability6,7"*

  Space the bolded word as: "non-respiratory illness, such as poor lung function, low birthweight, **nutritional deficiency**, and impairment of learning ability6,7".

- *"....still use biomass, mainly charcoal, wood, and agriculture residue, for cooking"*

  Can better read as: "....still use biomass mainly charcoal, wood and agriculture residue for cooking".

- *"..between biomass use for cooking and cardiovascular diseases, including CHD, hypertension, HC, diabetes, and stroke."*

  Can better read as: "...between biomass use for cooking and cardiovascular diseases including CHD, hypertension, HC, diabetes and stroke."

- *'The result could be used for disease prevention and control, and to support the global literature."*

  Can you better expatiate on this statement?

Methods:

- *"This is cross-sectional study."*

  Can better read as: "This is **a** cross-sectional study".

- I observed that the questionnaire was translated. What was the process used in the translation and maintaining its validity? I believe you need to address this.

- *"Ever smoker referred to those who smoke more than 100 cigarettes in their lifetime."*

  Can better read as: *"Ever smoker referred to those who have smoked more than 100 cigarettes in their lifetime."*

- *"....Living smoker.."*

  "Living with smoker"

- **Under the statistical analysis, could you add the explanation of how you derived your outcome variable of biomass and non-biomass use from the questionnaire?**

Results:

- *"The highest education levels were primary school or high school."*

  Rephrase this sentence.

- *"About 70% of the respondents reported using biomass for cooking (**Table 2**). However, when asked for fuel types that they usually use for cooking, 64.5% reported LPG and 32.3% charcoal. Among those who use charcoal, 38.6% use it often."*

Reading your response to one of the earlier peer reviewers, I would suggest you reanalyze your data using the participants' response of their fuel use type and further reclassify the different types of fuel types into biomass (wood, charcoal) and non-biomass user (LPG, electricity). From your questionnaire it appears question 16 and 17 should be from where you should derive the answer.

I expect that people are more likely to know what fuel type they use but may not be adequately informed to know technical terms like biomass fuel and non-biomass fuel.

All in all you need to be extremely clear on your definition of biomass use and this definition should be added to the method section as I believe some people may have primary and secondary use of fuel type of which Q17 from your questionnaire tries to address.

- Looking at this statement and the table it appears that over 65.4% of the participants are non-biomass users i.e. users of electricity and LPG. Please can you clarify how you derived the opposite i.e. that biomass users are 70%. This does not appear to tally with the figures on the table.

  Again the data is found in Table 1 and not Table 2, except you rename all your tables.

- Can you also clarify why "never users of charcoal" under the Frequency of using charcoal (495) is different from not use group under duration of use of charcoal (502).

- **It appears you may need to refine the headings to be more self–explanatory.**

- Under table 2: can the headings include the number of participants under each category e.g. Biomass, n (%) N=756.

- Be consistent in using one term for people not using biomass as in some places you used non-user group and in some others, gas users. Meanwhile did you aggregate electricity users and LPG users? If so you may need to state it.

- *"..and their family members also had more **incidence** of hypertension, HC, diabetes, and heart disease."*

Please replace as this study cannot assess for incidence but for prevalence.

- "..and their family members also had more prevalence of hypertension, HC, diabetes, and heart disease."

- In Table 4 put a superscript at R and F to explain what it is like in Table 3. It would have been good to label the continuation of Table 4.

- Is there any reason why you did not control for occupation and education in the logistic regression? Or don't you think they potentially can influence the results?

Discussion:

- *"This study presented an association between cardiovascular diseases and exposure to smoke from biomass, **mainly charcoal**, which is relatively cleaner when compared to wood, coal, or dung, a biomass which were often found in the literature."*

  If you planned to concentrate on charcoal then you should have clearly stated it and brought it out even in the result sections. It appears you may not have adequately brought this out in the write up and result so far. Again, any reference to show the statement you made that charcoal is cleaner than the others? I believe that is a statement that will need to be backed up with evidence and also should have been in the introduction.

- *Further analysis using logistic regression and control for potential confounder showed a significant OR of biomass use and **CHD(F), hypertension(F), HC(F), and diabetes(F)***

  I think it may be good to write the bolded in full.

- **The mentioned high cholesterol (HC) is instead a biochemical abnormality and not a disease condition.**

- I believe this is a major comment, you may need to address as it may cast a doubt on the findings related to this given variable as we would expect most people not to know their HC number except they have all been tested for it unlike being diagnosed of a disease.

- So is HC routinely carried out for the villagers? If yes by whom and are they told their results? HC is a risk factor for some of the NCDs.

- **If not I would suggest that this is deleted or it is clearly highlighted as doubtful.**

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
No

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public health, Epidemiology and Biostatistics, Health policy and health system research, Chronic diseases.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 09 October 2020

https://doi.org/10.5256/f1000research.29890.r72681

Nilima Barman
Department of Laboratory Medicine, Bangladesh Institute of Research and Rehabilitation for Diabetes, Endocrine and Metabolic Disorders (BIRDEM), Dhaka, Bangladesh

Now the article is more precise. The authors has addressed most of the review points from their point of view with clear justification.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Non communicable disease, Laboratory medicine, Public health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 22 September 2020

https://doi.org/10.5256/f1000research.25888.r71210

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Nilima Barman
Department of Laboratory Medicine, Bangladesh Institute of Research and Rehabilitation for Diabetes, Endocrine and Metabolic Disorders (BIRDEM), Dhaka, Bangladesh

The article has emphasized on detrimental effects of biomass cooking fuel on cardiovascular health. The results will help in future policy making regarding cooking fuel. The overall article is well-written but some of the issues need to be clarified as described below.

In the abstract:

1. The methods should be improved, giving a clear description of cooking fuel.

2. The author mentioned 'hypertension' in the objective, but high blood pressure (HBP) in the result section. Terminology should be consistent throughout the manuscript.

3. In the conclusion, the author stated, 'the study results were consistent with those found in studies from other parts of the world...'. This statement should be discussed in the discussion, not in the conclusion. The conclusion should be based on the authors' main findings.

In the introduction:

1. Please clarify the term 'Cooking smoke,' whether it means smoke from cooking or from fuel?

In the methods:

1. The study design is well articulated. But self-reported cardiovascular diseases may give a vague impression to the readers, although the author mentioned it as a limitation. In a matter of sense, the authors showed more than two-thirds (71.9 %) of participants had primary education who acted as self reporters of disease condition. So, in my opinion, the authors should have a strong justification in favor of including self-reported cardiovascular diseases with authentic scientific references.

2. Again, do the authors cross-check self-reported disease conditions with the patient's medical or laboratory reports or drug history? The mentioned high cholesterol (HC) is instead a biochemical abnormality apart from a disease condition.

In statistical analysis:

1. The regression model needs a precise description. Is it a multivariate or multinominal model?

2. In a logistic regression model, the cardiovascular disease condition of family members are also encountered. Are the adjusting confounding variables like age and sex in that regression model in relation of family members' age and sex, or the respondents'? It should be precisely mentioned in description of regression model.

In results:

1. It seems confusing between the data on 'Fuel use for cooking' in Table 1 and the total no of biomass and LPG users in Table 2. (In Table 1, LPG users are 695 participants, but in Table 2, it is 322 (by addition of 56 male and 266 female). Same for the biomass fuel. Please clarify it.

2. The footnote of Table 2 had a term '2-trail'. Is it trail or tail? Please correct it.

3. In Table 4, the significant value is given in bold letters. Please mention it.

In discussion:

1. In the 4th paragraph, the authors stated that 'We found about 10% of the respondents had type 2 diabetes'. It is hard to believe self-reported evidence of type 2 diabetes. Please clarify this or correct it.

In conclusion: the same as in abstract.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Non communicable disease, Laboratory medicine, Public health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 25 Sep 2020

Chudchawal Juntarawijit, Naresuan University, Phitsanulok, Thailand

Response to reviewer

In the abstract:

Comments: The methods should be improved, giving a clear description of cooking fuel.

Responses: A short description of cooking fuel was added to the methods section. Because F1000Research has set a maximum limit of 300 words for abstract, no more detailed information could be added.

Comments: The author mentioned 'hypertension' in the objective, but high blood pressure (HBP) in the result section. Terminology should be consistent throughout the manuscript.

Responses: The term “high blood pressure” was replaced by “hypertension”.

Comments: In the conclusion, the author stated, 'the study results were consistent with those found in studies from other parts of the world...'. This statement should be discussed

in the discussion, not in the conclusion. The conclusion should be based on the authors' main findings.

Responses: Yes, I agree that “the statement should be discussed in the discussion”. However, we believed we had already done that enough to justify the statement, which is our main finding.

In the introduction:

Comments: Please clarify the term 'Cooking smoke,' whether it means smoke from cooking or from fuel?

Responses: The meaning of cooking smoke was clarified and more information was added to the first paragraph in Introduction.

In the methods:

Comments: The study design is well articulated. But self-reported cardiovascular diseases may give a vague impression to the readers, although the author mentioned it as a limitation. In a matter of sense, the authors showed more than two-thirds (71.9 %) of participants had primary education who acted as self reporters of disease condition. So, in my opinion, the authors should have a strong justification in favor of including self-reported cardiovascular diseases with authentic scientific references.

Responses: Yes, I agree that using self-report data is a limitation of this study. However, since the data was collected by a well trained and experienced village health volunteer, the problem was expected to be minimal. The quality of the answer to this question may not depend much on their background education of respondents. In addition, this information bias, if occurred, will equally distribute among groups (case and control).

Comments: Again, do the authors cross-check self-reported disease conditions with the patient's medical or laboratory reports or drug history? The mentioned high cholesterol (HC) is instead a biochemical abnormality apart from a disease condition.

Responses: Yes, it is good if we can do the cross-check self-reported conditions. However, we did not do that.

In statistical analysis:

Comments: The regression model needs a precise description. Is it a multivariate or multinominal model?

Responses: Thank you for reminding.

In this study, we use binary multiple logistic regression.
More detail of the model was added to the statistic description.

Comments: In a logistic regression model, the cardiovascular disease condition of family members are also encountered. Are the adjusting confounding variables like age and sex in that regression model in relation of family members' age and sex, or the respondents'? It should be precisely mentioned in description of regression model.

Responses: Thank you to raise the issue. It is a good point which could be another limitation of this study. We didn't have enough information of the family members, so just use the data of the respondents.
More information was added in the description of the regression model.

In results:

Comments: It seems confusing between the data on 'Fuel use for cooking' in Table 1 and the total no of biomass and LPG users in Table 2. (In Table 1, LPG users are 695 participants, but in Table 2, it is 322 (by addition of 56 male and 266 female). Same for the biomass fuel. Please clarify it.

Responses: Table 1 showed data on what types of fuel the respondents usually use for cooking, and some of them use more than one fuel types. However, data in Table 2 was from another question which asked whether the respondents use biomass or not, and those who answered "no" was then classed as none biomass user or LPG user (assumed that only few use electric strove).

Comments: The footnote of Table 2 had a term '2-trail'. Is it trail or tail? Please correct it.

Responses: The error was corrected.

Comments: In Table 4, the significant value is given in bold letters. Please mention it.

Responses: The statement was added to Table 4 footnote.

In discussion:

Comments: In the 4th paragraph, the authors stated that 'We found about 10% of the respondents had type 2 diabetes'. It is hard to believe self-reported evidence of type 2 diabetes. Please clarify this or correct it.

Responses: Actually, we asked whether the respondents had ever been diagnosed by a medical doctor to have type 2 diabetes. Also the data was collected by village health volunteer, who were well trained as public health staff and know the disease which is very common in Thailand.

Competing Interests: No competing interests were disclosed.

Reviewer Report 19 May 2020

https://doi.org/10.5256/f1000research.25888.r62897

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A cross-sectional study undertaken to investigate a possible association between biomass use for cooking and cardiovascular diseases, including CHD, HBP, HC, diabetes, and stroke. Biomass users had a significantly higher prevalence of HBP, and HC, and their family members also had more incidence of HBP, HC, diabetes, and heart disease.

- In the abstract: Change "object" to "objective" of this study.
- The abbreviation “LPG" used from the abstract was not defined.
- The conclusion should be improved giving a summary of the findings first then move onto saying “these findings support those of..."

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public Health, Nutrition Epidemiology, Cardiovascular risk factors

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.