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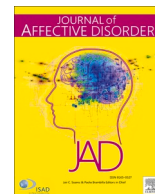


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## The association of cooking fuels with depression and anxiety symptoms among adults aged $\geq 65$ years from low- and middle-income countries

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### ABSTRACT

**Background:** We aimed to investigate associations of unclean cooking fuels with depression and anxiety symptoms in a large sample of adults aged  $\geq 65$  years from six low- and middle-income countries (LMICs).

**Methods:** Cross-sectional, community-based, nationally representative data from the WHO Study on global AGEing and adult health (SAGE) were analyzed. Unclean cooking fuel referred to kerosene/paraffin, coal/charcoal, wood, agriculture/crop, animal dung, and shrubs/grass. Depression referred to DSM-IV depression based on past 12-month symptoms or receiving depression treatment in the last 12 months. Anxiety symptoms referred to severe/extreme problems with worry or anxiety in the past 30 days. Multivariable logistic regression analysis and meta-analysis were conducted.

**Results:** Data on 14,585 people aged  $\geq 65$  years were analyzed [mean (SD) age 72.6 (11.5) years; maximum age 114 years; 55.0% females]. After adjustment for potential confounders, unclean cooking fuel was associated with a significant 2.52 (95%CI = 1.66–3.82) times higher odds for depression with a low level of between-country heterogeneity ( $I^2 = 0.0\%$ ). For anxiety symptoms, unclean fuel use was not significantly associated with anxiety symptoms (OR = 1.13; 95%CI = 0.77–1.68;  $I^2 = 0.0\%$ ).

**Limitations:** 1. Cross-sectional design. 2. Self-reported measures. 3. No information about outdoor pollution exposure, personal exposure, and smoke composition of different cooking fuels.

**Conclusions:** Unclean cooking fuel was significantly associated with higher odds for depression, but not anxiety, with little observed variability between settings. Findings from the present study provide further support and call for action in appropriate implementation of the United Nations Sustainable Goal 7, which advocates affordable, reliable, sustainable, and modern energy for all.

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## 1. Introduction

Due to rapid population ageing occurring globally, the prevalence and incidence of late-life common mental disorders such as anxiety and depression is likely to increase substantially in the coming years especially in low- and middle-income countries (LMICs), where the speed of ageing is outpacing that of high-income countries (HICs) (Department of Economic and Social Affairs, 2019). This is of concern as late-life depression and anxiety are associated with greater risk for morbidity, increased use of hospital and outpatient medical services, disability, psychosocial adversity, neurologic comorbidity, suicide, worse quality of life, and premature mortality (Alexopoulos et al., 2002; Blazer, 2003; Hellwig and Domschke, 2019; Meier et al., 2016; Wei et al., 2019). Furthermore, in the context of LMICs, late-life depression and anxiety may have a particularly pronounced negative impact given that more than 75% of people in LMICs receive no treatment for mental disorders despite the existence of effective treatments (Evans-Lacko et al., 2018). Thus, it is important to identify risk factors of late-life common mental disorders in LMICs to inform targeted interventions.

One understudied but potentially important risk factor for common mental disorders among older people in LMICs is use of unclean cooking fuels, which includes kerosene/paraffin, and solid fuels (coal/charcoal, wood, agriculture/crop, animal dung, shrubs/grass). Globally, approximately 3 billion people use traditional biomass such as fuelwood, which has detrimental health and environmental effects on households and the world at large, as their main source of cooking fuels. Out of these 3 billion people, it is estimated that almost 2.6 million are residents of LMICs (Twumasi et al., 2021). Unclean cooking fuels may increase risk for common mental disorders via, for example, higher levels of household air pollution, which is associated with oxidative stress and inflammation that are implicated in the pathogenesis of depression and anxiety (Shao et al., 2021). Furthermore, this may be a particularly important risk factor for mental health problems among the older population as they are more likely to spend time indoors.

Currently, there is a small body of literature to support the notion that unclean fuel use may increase the risk of depression and anxiety. One cross-sectional study found that cooking with biomass was associated with higher odds for depressive symptoms (OR = 1.67; 95%CI = 1.18–2.95) in 1756 pre-menopausal women in India (Banerjee et al., 2012). Another case-control study found that current solid fuel use (either for heating or cooking) was positively associated with higher odds for depressive symptoms (OR = 1.28; 95%CI = 1.15–1.44) among 9107 middle-aged and older people in China (Liu et al., 2020). Furthermore, in a longitudinal study including four years of follow-up carried out on 8637 middle-aged to older age adults in China, unclean cooking fuel was associated with a higher incidence of depressive symptoms (HR = 1.12; 95%CI = 1.02–1.24) (Shao et al., 2021). More recently, one cross-sectional study from China investigated the association between use of biomass fuel for cooking and depression or anxiety symptoms among 13,361 adults aged  $\geq 65$  years. This study found that biomass fuel use was associated with 1.23 (95%CI = 1.03–1.47) and 1.31 (95%CI = 1.02–1.68) times higher odds for depression and anxiety symptoms, respectively (Deng et al., 2021).

To the best of the authors' knowledge, no other literature exists on this topic. Existing literature has several limitations including the focus on only two LMICs (i.e., India and China), while the study from India only included a sample of pre-menopausal females, severely limiting generalizability. Furthermore, there is only one previous study on unclean cooking fuel and anxiety. Thus, more research is needed to assess whether the results can be corroborated in other settings.

Given this background, the aim of the present study was to investigate associations of unclean cooking fuels with depression and anxiety symptoms in a sample of 14,585 people aged  $\geq 65$  years from six LMICs (China, Ghana, India, Mexico, Russia, South Africa). We hypothesized that unclean cooking fuel use will be associated with higher odds of anxiety and depression symptoms.

## 2. Methods

Data from the Study on Global Ageing and Adult Health (SAGE) were analyzed. Details of the survey methodology have been published elsewhere (Kowal et al., 2012). In brief, this survey was undertaken in China, Ghana, India, Mexico, Russia, and South Africa between 2007 and 2010. These countries broadly represent different geographical locations and levels of socio-economic and demographic transition. Based on the World Bank classification at the time of the survey, Ghana was the only low-income country, and China and India were lower middle-income countries although China became an upper middle-income country in 2010. The remaining countries were upper middle-income countries. In order to obtain nationally representative samples, a multistage clustered sampling design method was used. The sample consisted of adults aged  $\geq 18$  years with oversampling of those aged  $\geq 50$  years. Trained interviewers conducted face-to-face interviews using a standard questionnaire. Standard translation procedures were undertaken to ensure comparability between countries. The survey response rates were: China 93%; Ghana 81%; India 68%; Mexico 53%; Russia 83%; and South Africa 75%. Sampling weights were constructed to adjust for non-response and the population structure as reported by the United Nations Statistical Division. Ethical approval was obtained from the WHO Ethical Review Committee and local ethics research review boards. Written informed consent was obtained from all participants.

### 2.1. Cooking fuel

Information on the type of cooking fuel used in the household was obtained by the question "What type of fuel does your household mainly use for cooking?" with the following answer options: gas, electricity, kerosene/paraffin, coal/charcoal, wood, agriculture/crop, animal dung, and shrubs/grass. In line with a previous SAGE publication (Li et al., 2021), this variable was dichotomized as clean fuels (gas, electricity), and non-clean fuels [kerosene/paraffin, solid fuels (coal/charcoal, wood, agriculture/crop, animal dung, shrubs/grass)].

### 2.2. Depression

Questions based on the World Mental Health Survey version of the Composite International Diagnostic Interview (Kessler and Üstün, 2004) were used for the endorsement of past 12-month DSM-IV depression using the same algorithm used in previous studies using the same dataset (Garin et al., 2016; Koyanagi et al., 2014) (Details provided in Table S1 of the Appendix). Individuals who reported to have received treatment for depression in the past 12 months were also considered to have depression.

### 2.3. Control variables

The control variables were selected based on past literature (Liu et al., 2020), and included age, sex, setting (rural or urban), education (years), wealth quintiles based on income, marital status (currently married/cohabiting or else), unemployment, smoking (never, current, past), alcohol consumption in the past 30 days, sleep problems, body mass index (BMI), number of chronic conditions, disability, and social participation. Unemployment referred to not being engaged in paid work  $\geq 2$  days in the last 7 days. Sleep problems were assessed by the question "Overall in the last 30 days, how much of a problem did you have with sleeping, such as falling asleep, waking up frequently during the night or waking up too early in the morning?" with answer options 'none', 'mild', 'moderate', 'severe', and 'extreme'. Those who answered 'severe' and 'extreme' were considered to have sleep problems (Koyanagi et al., 2014; Koyanagi and Stickley, 2015). BMI was calculated as weight in kilograms divided by height in meters squared based on measured weight and height. BMI was categorized as  $< 18.5$  kg/m<sup>2</sup> (underweight), 18.5–24.9 kg/m<sup>2</sup> (normal weight), 25.0–29.9 kg/m<sup>2</sup>

(overweight), and  $\geq 30.0$  kg/m<sup>2</sup> (obesity) (World Health Organization, 2000). Information on 11 chronic physical diseases (angina, arthritis, asthma, chronic back pain, chronic lung disease, diabetes, edentulism, hearing problem, hypertension, stroke, visual impairment) were obtained. The details on the diagnosis of these conditions are provided in **Table S2** (Appendix). The number of chronic conditions was summed and categorized as 0, 1, and  $\geq 2$ . Disability was assessed with six questions on the level of difficulty in conducting standard basic activities of daily living (ADL) in the past 30 days (washing whole body, getting dressed, moving around inside home, eating, getting up from lying down, and using the toilet). Those who answered severe or extreme/cannot do to any of the six questions were considered to have disability (Koyanagi et al., 2015). Following a previous SAGE publication (Ma et al., 2021), a social participation scale was created based on nine questions on the participant's involvement in community activities in the past 12 months (e.g., attended religious services, club, society, union etc.) with answer options 'never (coded = 1)', 'once or twice per year (coded=2)', 'once or twice per month (coded=3)', 'once or twice per week (coded=4)', and 'daily (coded = 5)'. The answers to these questions were summed and converted to a scale ranging from 0 to 100 with higher scores indicating higher levels of social participation.

#### 2.4. Statistical analysis

The statistical analysis was performed with Stata 14.2 (Stata Corp LP, College station, Texas). The analysis was restricted to those aged  $\geq 65$  years. The difference in sample characteristics was tested by Chi-squared tests and Student's *t*-tests for categorical and continuous variables, respectively. We conducted country-wise multivariable logistic regression analysis to assess the association between cooking fuel (exposures) and depression or anxiety (outcomes). The regression analysis was adjusted for age, sex, setting, education, wealth, marital status, unemployment, smoking, alcohol consumption, sleep problems, body mass index, number of chronic conditions, disability, and social participation. Furthermore, in order to assess the between-country heterogeneity that may exist in the association between cooking fuel and depression or anxiety symptoms, we calculated the Higgins's *I*<sup>2</sup> based on estimates from each country. The Higgins's *I*<sup>2</sup> represents the degree of heterogeneity that is not explained by sampling error with a value of  $<40\%$  often considered as negligible and 40–60% as moderate heterogeneity (Higgins and Thompson, 2002). A pooled estimate was obtained by fixed-effect meta-analysis. All variables were included in the models as categorical variables with the exception of age, years of education, and social participation (continuous variable). The sample weighting and the complex study design were taken into account in the analyses. Results from the regression analyses are presented as ORs with 95% CIs. The level of statistical significance was set at  $P < 0.05$ .

### 3. Results

The final sample included 14,585 people aged  $\geq 65$  years [mean (SD) age 72.6 (11.5) years; maximum age 114 years; 55.0% females]. The sample sizes by country were: China  $n = 5360$ ; Ghana  $n = 1975$ ; India  $n = 2441$ ; Mexico  $n = 1375$ ; Russia  $n = 1950$ ; South Africa  $n = 1484$ . The sample characteristics are provided in **Table 1**. The overall prevalence of depression and anxiety symptoms were 7.1% and 9.7%, respectively. Compared to clean cooking fuel, unclean cooking fuel was associated with significantly higher prevalence of depression, anxiety symptoms, male sex, rural setting, being employed, lower levels of wealth, smoking, sleep problems, low BMI, and disability, while it was also associated with slightly younger age and with lower levels of education, and higher levels of social participation. The prevalence of unclean fuel use overall was 45.9%, and this varied widely between countries, ranging from 1.6% in Russia to 92.8% in Ghana (**Fig. 1**). The country-wise association between unclean fuel use for cooking and depression is shown in **Fig. 2**. After adjustment for potential confounders, unclean fuel use was

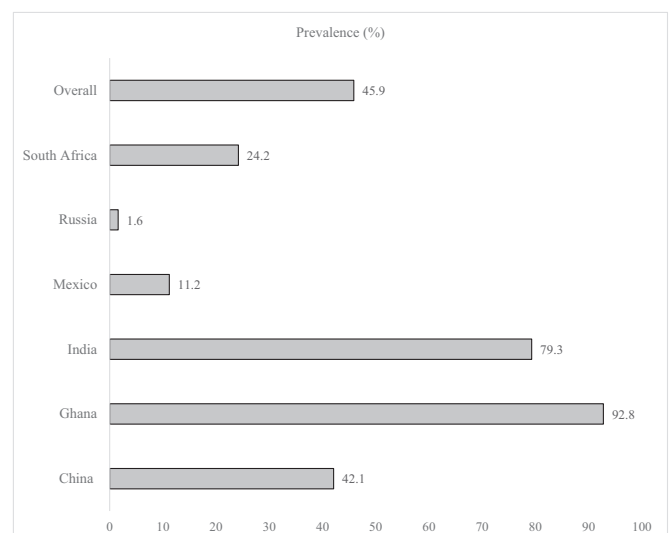
**Table 1**  
Sample characteristics (overall and by type of cooking fuel).

Characteristics		Cooking fuel			P-value <sup>a</sup>
		Overall	Clean	Unclean	
Depression	No	92.9	96.6	88.6	<0.001
	Yes	7.1	3.4	11.4	
Anxiety symptoms	No	90.3	94.8	84.9	<0.001
	Yes	9.7	5.2	15.1	
Age (years)	Mean (SD)	72.6 (11.5)	73.0 (11.5)	72.0 (11.3)	<0.001
	Sex	Female	55.0	58.5	50.8
Setting	Male	45.0	41.5	49.2	<0.001
	Urban	50.6	79.6	16.5	
Education (years)	Rural	49.4	20.4	83.5	<0.001
	Mean (SD)	5.2 (9.3)	7.6 (9.2)	2.3 (6.2)	
Wealth	Poorest	21.7	13.4	31.4	<0.001
	Poorer	21.0	16.2	26.8	
	Middle	20.4	21.6	19.0	
	Richer	17.5	20.5	14.0	
	Richest	19.4	28.3	8.9	
Marital status	Married/cohabiting	61.0	59.0	63.5	0.0539
	Else	39.0	41.0	36.5	
Unemployment	No	21.6	10.6	34.7	<0.001
	Yes	78.4	89.4	65.3	
Smoking	Never	62.2	73.7	48.7	<0.001
	Current	29.3	16.4	44.5	
Alcohol consumption	Quit	8.5	9.9	6.8	0.2063
	No	86.1	85.3	87.0	
Sleep problems	Yes	13.9	14.7	13.0	<0.001
	No	87.8	90.3	84.7	
Body mass index	Yes	12.2	9.7	15.3	<0.001
	Underweight	19.3	6.0	34.3	
	Normal	46.4	43.1	49.9	
	Overweight	23.9	34.3	12.3	
No. of chronic conditions	Obese	10.4	16.6	3.5	<0.001
	0	14.5	11.7	17.9	
	1	27.7	25.7	30.0	
	$\geq 2$	57.8	62.6	52.1	
Disability	No	88.1	90.4	85.4	<0.001
	Yes	11.9	9.6	14.6	
Social participation <sup>b</sup>	Mean (SD)	18.5 (23.9)	17.2 (22.7)	20.1 (24.7)	<0.001

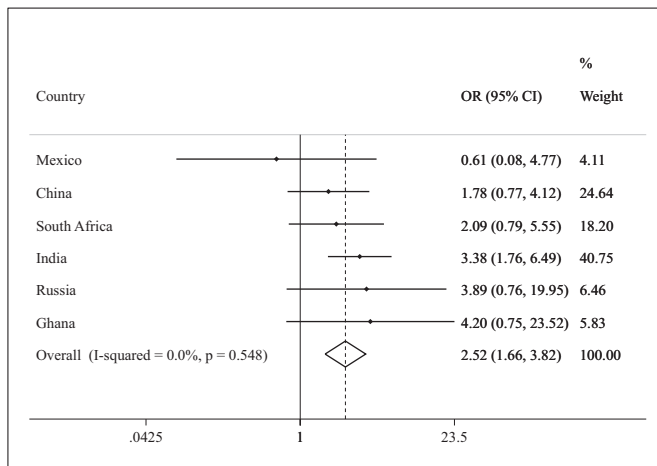
Abbreviation: SD Standard deviation.

<sup>a</sup> *P*-values were obtained by Chi-squared tests and Student's *t*-tests for categorical and continuous variables, respectively.

<sup>b</sup> Social participation was based on a scale ranging from 0 to 100 with higher scores representing higher levels of social participation.

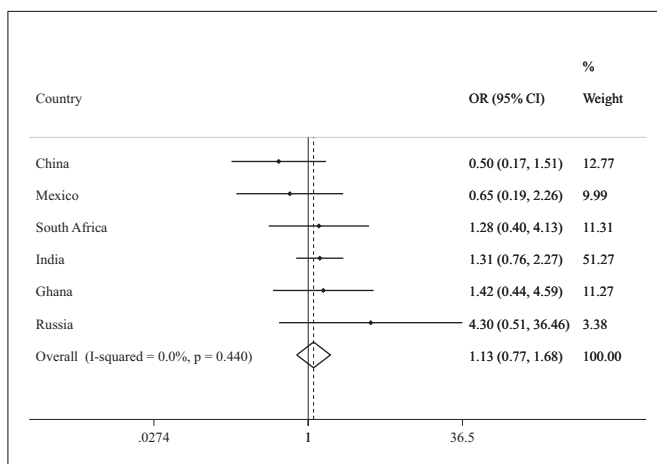


**Fig. 1.** Prevalence of unclean fuel use for cooking (overall and by country).



**Fig. 2.** Country-wise association between unclean fuel use for cooking and depression (outcome) estimated by multivariable logistic regression. Abbreviation: OR Odds ratio; CI Confidence interval. Models are adjusted for age, sex, setting, education, wealth, marital status, unemployment, smoking, alcohol consumption, sleep problems, body mass index, number of chronic conditions, disability, and social participation. Overall estimate was obtained by meta-analysis with fixed effects.

associated with higher odds for depression (i.e., OR > 1) in all countries except Mexico, with this being statistically significant only in India at the individual country level. The overall estimate based on a meta-analysis showed that unclean cooking fuel use is associated with a significant 2.52 (95%CI = 1.66–3.82) times higher odds for depression with a low level of between-country heterogeneity ( $I^2 = 0.0\%$ ). For anxiety symptoms, unclean fuel use was associated with higher odds for anxiety symptoms in South Africa, India, Ghana, and Russia but not in China and Mexico with no statistical significance being observed at the individual country level (Fig. 2). Overall, unclean fuel use was not significantly associated with anxiety symptoms (OR = 1.13; 95%CI = 0.77–1.68;  $I^2 = 0.0\%$ ) (Fig. 3).



**Fig. 3.** Country-wise association between unclean fuel use for cooking and anxiety symptoms (outcome) estimated by multivariable logistic regression. Abbreviation: OR Odds ratio; CI Confidence interval. Models are adjusted for age, sex, setting, education, wealth, marital status, unemployment, smoking, alcohol consumption, sleep problems, body mass index, number of chronic conditions, disability, and social participation. Overall estimate was obtained by meta-analysis with fixed effects.

## 4. Discussion

### 4.1. Main findings

In this large sample of adults aged  $\geq 65$  years from six LMICs, unclean cooking fuel use was associated with a significant 2.52 (95%CI = 1.66–3.82) times higher odds for depression with a low level of between-country heterogeneity ( $I^2 = 0.0\%$ ). No significant associations were observed between unclean cooking fuel use and anxiety symptoms. To the best of our knowledge, this is the first multicountry study on unclean cooking fuel and common mental disorders.

### 4.2. Interpretation of the findings

The findings from the present study are in line with previous studies on unclean cooking fuel and depression conducted among older adults in China and premenopausal women in India (Banerjee et al., 2012; Deng et al., 2021; Liu et al., 2020; Shao et al., 2021). The present findings add to the existing literature by demonstrating a positive association between unclean cooking fuel and depression in a large representative sample of older adults from six LMICs with little variability between settings. Furthermore, our study suggests that unclean cooking fuel is not associated with anxiety symptoms that contradict the only other study on this topic, carried out in China (Deng et al., 2021).

There are several plausible pathways that may explain the link between unclean cooking fuels and depression. First, as previously mentioned, such fuels are associated with higher levels of household air pollution, which is associated with oxidative stress and inflammation that are implicated in the pathogenesis of depression (Shao et al., 2021). Second, particulate matter, produced through unclean cooking fuel, may induce metabolic alterations that are consistent with the activation of the hypothalamus-pituitary-adrenal axis (Li et al., 2017). Activation of the hypothalamus-pituitary-adrenal axis is common among those who are depressed (Varghese and Brown, 2001). Third, particulate matter exposure has been found to be associated with a significant increase in serum levels of stress hormones (Li et al., 2017). Prolonged secretion of the stress hormone cortisol has been implicated in the pathogenesis of depression (Qin et al., 2016).

It should be noted that the null association observed in the present study between unclean cooking fuel and anxiety symptoms contradicts the only other study on this topic that found that use of biomass fuel for cooking is associated with a higher odds of anxiety compared to clean fuel in China (Deng et al., 2021). The reason for the differing findings is unclear but it may be speculated that the difference may be partly explained by different methodology. For example, the present study included biomass fuels as well as kerosene/paraffin whereas the only other study on this topic included only biomass fuel. Furthermore, the other study used the 7-item Generalized Anxiety Disorder Scale for the assessment of anxiety whereas our study used a single-item question. Alternatively, this may also be due to the different control variables used. For instance, our study adjusted for social participation and sleep problems but the other study did not adjust for these factors. Future studies with anxiety as the outcome from more diverse settings are necessary to provide more concrete information on whether unclean cooking fuel is associated with anxiety.

### 4.3. Implications of findings

Findings from the present study suggest that it may be important to implement interventions or policies to reduce unclean cooking fuel use in LMICs to aid in the prevention of depression. Indeed, the United Nations Sustainable Goal 7 includes a target to ensure access to affordable, reliable, sustainable, and modern energy for all, as this is likely to improve multiple health outcomes. Thus, reduction in unclean cooking fuel use has been identified as a priority on the international stage (Sustainable Development Goals, 2021). The following is currently

being suggested by key international bodies such as the World Health Organization to address the common use of unclean cooking fuel in LMICs: 1) Governments must prioritize clean-cooking solutions (i.e., access to clean and modern cooking energy), via evidence-based policies and strategies. 2) Mobilization of funds to scale up promising enterprises, so they become profitable, increase consumer choice and financing, and stimulate additional private investment. 3) Successful clean-cooking solutions should engage diverse public and private stakeholders. 4) Moving people towards cleaner and more efficient cooking solutions that meet local cultural, social and gender needs should be prioritized. 5) Improved monitoring of household energy use to track, measure impact, and assess progress towards achieving universal access (United Nations, 2018). Future research can explicitly connect these efforts to a multi-pronged and systemic strategy to prevent depression and improve overall health in the population.

#### 4.4. Strengths and limitations

The large representative sample of older adults from multiple LMICs is clear strengths of the present study. However, findings must be interpreted in light of the study limitations. First, the study is cross-sectional in nature and thus, temporal associations or causality cannot be established. Second, the majority of measures in the present study were self-reported potentially introducing recall and social desirability bias into the findings. Third, we were unable to account for outdoor pollution exposure (smog and soot), which has been linked to mental health problems and may have confounded our findings (Buoli et al., 2018). Fourth, depression and anxiety symptoms were not based on a clinical assessment. Relatedly, anxiety symptoms were based on a single-item question, but the use of extreme categories (i.e., ‘severe’ and ‘extreme’) to identify those with anxiety symptoms is likely to have improved specificity. Finally, there was no information on personal exposure (including length of time or frequency) and smoke composition of different cooking fuels. Future studies should take these factors into consideration to provide more insight.

#### 5. Conclusion

In this large sample of adults aged  $\geq 65$  years from six LMICs, it was observed that the use of unclean cooking fuel is associated with significantly higher odds for depression, but not anxiety symptoms, with little observed variability between settings. Findings from the present study provide further support and call for action in appropriate implementation of the United Nations Sustainable Goal 7. For example, this may be achieved by governments prioritizing clean-cooking solutions and mobilizing funds to scale up promising enterprises.

#### Ethics

Ethical approval was obtained from the WHO Ethical Review Committee and local ethics research review boards. Written informed consent was obtained from all participants.

#### CRedit authorship contribution statement

All authors have made a substantial, direct and intellectual contribution to the work. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

#### Role of the funding source

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#### Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jad.2022.05.103>.

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