**Title:** The association of cooking fuels with depression and anxiety symptoms among adults aged ≥65 years from low- and middle-income countries

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# 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 pathogeneses 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 13361 adults aged ≥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 14585 people aged ≥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.

# 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 ≥18 years with oversampling of those aged ≥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.

## 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, X., 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)].

## 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.

## 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 ≥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/m2 (underweight), 18.5-24.9 kg/m2 (normal weight), 25.0-29.9 kg/m2 (overweight), and ≥30.0 kg/m2 (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 ≥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.

## Statistical analysis

The statistical analysis was performed with Stata 14.2 (Stata Corp LP, College station, Texas). The analysis was restricted to those aged ≥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*2 based on estimates from each country. The Higgins’s *I*2 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.

# RESULTS

The final sample included 14585 people aged ≥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 (**Figure 1**). The country-wise association between unclean fuel use for cooking and depression is shown in **Figure 2**. After adjustment for potential confounders, unclean fuel use was 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 (*I2*=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 (**Figure 2**). Overall, unclean fuel use was not significantly associated with anxiety symptoms (OR=1.13; 95%CI=0.77-1.68; *I2*=0.0%).

# DISCUSSION

## Main findings

In this large sample of adults aged ≥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 (*I2*=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.

## 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 contradicts 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 pathogeneses 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, H., 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, H., et al, 2017). Prolonged secretion of the stress hormone cortisol has been implicated in the pathogeneses 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.

## 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.

## Strengths and limitations

The large representative sample of older adults from multiple LMICs are 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.

## Conclusion

In this large sample of adults aged ≥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.

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# TABLES AND FIGURES

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| **Table 1** Sample characteristics (overall and by type of cooking fuel) | | | | | |
|  |  |  | Cooking fuel | |  |
| Characteristics |  | Overall | Clean | Unclean | P-valuea |
| 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 | <0.001 |
|  | Male | 45.0 | 41.5 | 49.2 |  |
| Setting | Urban | 50.6 | 79.6 | 16.5 | <0.001 |
|  | Rural | 49.4 | 20.4 | 83.5 |  |
| Education (years) | Mean (SD) | 5.2 (9.3) | 7.6 (9.2) | 2.3 (6.2) | <0.001 |
| 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 |  |
|  | Quit | 8.5 | 9.9 | 6.8 |  |
| Alcohol consumption | No | 86.1 | 85.3 | 87.0 | 0.2063 |
|  | Yes | 13.9 | 14.7 | 13.0 |  |
| Sleep problems | No | 87.8 | 90.3 | 84.7 | <0.001 |
|  | Yes | 12.2 | 9.7 | 15.3 |  |
| Body mass index | Underweight | 19.3 | 6.0 | 34.3 | <0.001 |
|  | Normal | 46.4 | 43.1 | 49.9 |  |
|  | Overweight | 23.9 | 34.3 | 12.3 |  |
|  | Obese | 10.4 | 16.6 | 3.5 |  |
| No. of chronic conditions | 0 | 14.5 | 11.7 | 17.9 | <0.001 |
|  | 1 | 27.7 | 25.7 | 30.0 |  |
|  | ≥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 participationb | Mean (SD) | 18.5 (23.9) | 17.2 (22.7) | 20.1 (24.7) | <0.001 |

Abbreviation: SD Standard deviation

a P-values were obtained by Chi-squared tests and Student’s *t*-tests for categorical and continuous variables, respectively.

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

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

**Chart**

**Figure 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.

Chart

**Figure 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.

# APPENDIX

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| **Table S1** Questions and answer options used for endorsement of DSM-IV depression |
| 1. At least one of the two following symptoms in the last 12 months: |
| (a) A period, lasting several days, of feeling sad, empty or depressed |
| (b) A period lasting several days with a loss of interest in most things the participant usually enjoys such as personal relationships, work or hobbies/recreation |
| **AND** |
| 2. The period of sadness/loss of interest/low energy lasted for more than two weeks and was most of the day and nearly every day |
| **AND** |
| 3. Five or more of the following symptoms: |
| (a) Loss of appetite |
| (b) Insomnia (problems falling asleep or waking up too early) |
| (c) Decreased energy or tiredness all the time |
| (d) Slowing down in moving around or restless/jittery |
| (e) Negative feelings/loss of confidence or frequent feelings of hopelessness. |
| (f) Slowed thinking or difficulties concentrating (e.g., listening to others, working, watching TV, listening to the radio) |
| (g) Thoughts of death, wishes of own death or suicide attempt |
| (h) Feelings of sadness, emptiness or depression lasting several days |
| (i) Anhedonia: loss of interest in things the participant usually enjoys |

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| **Table S2** Details on the diagnosis of chronic conditions | | |
| Condition | (a) Self-reported diagnosis or symptoms | (b) Symptom-based algorithm or other method of diagnosis |
| Angina | Have you ever been diagnosed with angina or angina pectoris (a heart disease)? | Rose questionnaire |
| Arthritis | Have you ever been diagnosed with/told you have arthritis (a disease of the joints, or by other names rheumatism or osteoarthritis)? | NA |
| Asthma | Have you ever been diagnosed with asthma (an allergic respiratory disease)? | NA |
| Chronic back pain | Back pain everyday during the last 30 days. | NA |
| Chronic lung disease | Have you ever been diagnosed with chronic lung disease (emphysema, bronchitis, COPD)? | NA |
| Diabetes | Have you ever been diagnosed with diabetes (high blood sugar)? (not including diabetes associated with a pregnancy) | NA |
| Edentulism | Have you lost all of your natural teeth? | NA |
| Hearing problem | NA | Interviewer observation |
| Hypertension | Have you ever been diagnosed with high blood pressure (hypertension)? | Blood pressure was measured three times with a one-minute interval with the use of a wrist blood pressure monitor (Medistar Wrist Blood Pressure Model S) and the mean value of the three measurements was calculated. Hypertension was defined as having at least one of the following: systolic blood pressure ≥140 mmHg; diastolic blood pressure ≥90 mmHg. |
| Stroke | Have you ever been told by a health professional that you have had a stroke? | NA |
| Visual impairment | Severe/extreme difficulty in seeing and recognizing a person that the participant knows across the road | NA |