



Food insecurity and insomnia-related symptoms among adults from low- and middle-income countries

Jacob, L., Smith, L., Kostev, K., Oh, H., Gyasi, R. M., Sánchez, G. F. L., Song, T.J., Tully, M. A., Haro, J. M., Yon, D. K., Shin, J. I., & Koyanagi, A. (2023). Food insecurity and insomnia-related symptoms among adults from low- and middle-income countries. *Journal of Sleep Research*, 32(4), 1-10. Article e13852. <https://doi.org/10.1111/jsr.13852>

[Link to publication record in Ulster University Research Portal](#)

Published in:
Journal of Sleep Research

Publication Status:
Published (in print/issue): 21/02/2023

DOI:
[10.1111/jsr.13852](https://doi.org/10.1111/jsr.13852)

Document Version
Author Accepted version

General rights
Copyright for the publications made accessible via Ulster University's Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy
The Research Portal is Ulster University's institutional repository that provides access to Ulster's research outputs. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact pure-support@ulster.ac.uk.

Food insecurity and insomnia-related symptoms among adults from low- and middle-income countries

Running head: Food insecurity and insomnia-related symptoms

Louis Jacob, MD-PhD (ORCID: 0000-0003-1071-1239)^{a,b,c}; Lee Smith, PhD (ORCID: 0000-0002-5340-9833)^d; Karel Kostev, PhD (ORCID: 0000-0002-2124-7227)^e; Hans Oh, PhD (ORCID: 0000-0002-8458-8723)^f; Razak M. Gyasi, PhD (ORCID: 0000-0002-6733-1539)^g; Guillermo F. López Sánchez, PhD (ORCID: 0000-0002-9897-5273)^h; Tae-Jin Song, MD-PhD (ORCID: 0000-0002-9937-762X)ⁱ; Mark A. Tully, PhD (ORCID: 0000-0001-9710-4014)^j; Josep Maria Haro, MD-PhD (ORCID: 0000-0002-3984-277X)^a; Dong Keon Yon, MD (ORCID: 0000-0003-1628-9948)^k; Jae Il Shin, MD-PhD (ORCID: 0000-0003-2326-1820)^l; Ai Koyanagi, MD-PhD (ORCID: 0000-0002-9565-5004)^{a,m}

^a Research and Development Unit, Parc Sanitari Sant Joan de Déu, CIBERSAM, ISCIII, Dr. Antoni Pujadas, 42, Sant Boi de Llobregat, Barcelona, Spain

^b Department of Physical Medicine and Rehabilitation, Lariboisière-Fernand Widal Hospital, AP-HP, University Paris Cité, Paris, France

^c Faculty of Medicine, University of Versailles Saint-Quentin-en-Yvelines, Montigny-le-Bretonneux, France

^d Centre for Health, Performance, and Wellbeing, Anglia Ruskin University, Cambridge CB1 1PT, United Kingdom

^e University clinic of Marburg, Marburg, Germany

^f Suzanne Dworak Peck School of Social Work, University of Southern California, Los Angeles, CA, United States

^g Aging and Development Unit, African Population and Health Research Center, Nairobi, Kenya

^h Division of Preventive Medicine and Public Health, Department of Public Health Sciences, School of Medicine, University of Murcia, Murcia, Spain 11

ⁱ Department of Neurology, Seoul Hospital, Ewha Womans University, South Korea

^j School of Medicine, Ulster University, Londonderry, Northern Ireland, United Kingdom

^k Center for Digital Health, Medical Science Research Institute, Kyung Hee University College of Medicine, Seoul, South Korea

^l Department of Pediatrics, Yonsei University College of Medicine, Seoul, Republic of Korea

^m Institució Catalana de Recerca i Estudis Avançats (ICREA), Pg. Lluís Companys 23,
Barcelona, Spain

Corresponding author:

Louis Jacob, MD-PhD

Research and Development Unit

Barcelona 08830

Spain

E-mail: louis.jacob.contacts@gmail.com

Tel.: +33-6-27-88-37-06

Article type: Research article

Number of characters in the title (spaces included): 96

Number of characters in the running head (spaces included): 45

Number of words in the abstract: 248

Number of words in the main body: 4,197

Number of references: 50

Number of tables: 3

Number of figures: 2

Number of appendixes: 1

Acknowledgments

This paper uses data from WHO's Study on Global AGEing and Adult Health (SAGE).

SAGE is supported by the U.S. National Institute on Aging through Interagency Agreements OGHA 04034785, YA1323–08-CN-0020, Y1-AG-1005–01 and through research grants R01-AG034479 and R21-AG034263.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare no competing financial interests.

Author contributions

Louis Jacob: Conceptualization, Methodology, Writing - original draft, and Writing - review & editing. Lee Smith: Conceptualization, Writing - review & editing. Karel Kostev: Conceptualization, Writing - review & editing. Hans Oh: Conceptualization, Writing – review & editing. Razak M. Gyasi: Conceptualization, Writing - review & editing. Guillermo F. López Sánchez: Conceptualization, Writing - review & editing. Tae-Jin Song: Conceptualization, Writing - review & editing. Mark A. Tully: Conceptualization, Writing - review & editing. Josep Maria Haro: Conceptualization, Writing - review & editing. Dong Keon Yon: Conceptualization, Writing - review & editing. Jae Il Shin: Conceptualization, Writing - review & editing. Ai Koyanagi: Conceptualization, Formal analysis, Methodology, Supervision, Writing - original draft, and Writing - review & editing. All authors contributed to and have approved the final manuscript.

Ethics committee approval

The WHO Ethical Review Committee and local ethics research review boards provided ethical approval.

Informed consent

All participants gave written informed consent.

Abstract

Little is known about the relationship between food insecurity and sleep problems in low- and middle-income countries (LMICs), while the mediators of this association are largely unknown. Therefore, we investigated the association between food insecurity and insomnia-related symptoms in six LMICs (i.e., China, Ghana, India, Mexico, Russia, South Africa), and the potential mediators of this relationship. Cross-sectional, nationally representative data from the Study on Global AGEing and Adult Health (SAGE; 2007-2010) were analyzed. Past 12-month food insecurity was assessed with two questions on frequency of eating less and hunger owing to lack of food. Insomnia-related symptoms referred to severe or extreme sleep problems in the past 30 days. Multivariable logistic regression and mediation analysis were conducted. Data on 42,489 adults aged ≥ 18 years were analyzed (mean [SD] age 43.8 [14.4] years; 50.1% females). The prevalence of any food insecurity and insomnia-related symptoms was 11.9% and 4.4%, respectively. After adjustment, compared to no food insecurity, moderate (OR=1.53, 95%CI=1.11-2.10) and severe food insecurity (OR=2.35, 95% CI=1.56-3.55) were significantly associated with insomnia-related symptoms. Anxiety, perceived stress, and depression mediated 27.7%, 13.5%, and 12.5% of the relationship between any food insecurity and insomnia-related symptoms, respectively (total percentage=43.3%). Food insecurity was positively associated with insomnia-related symptoms in adults from six LMICs. Anxiety, perceived stress, and depression explained a substantial proportion of this relationship. Addressing food insecurity itself or the identified potential mediators among people with food insecurity may lead to reduction in sleep problems among adults in LMICs, pending confirmation with longitudinal studies.

Keywords: food insecurity; sleep problems; insomnia-related symptoms; low- and middle-income countries; epidemiology

Introduction

Sleep problems, also known as sleep disturbances, correspond to a wide range of sleep-related symptoms, such as difficulties in falling asleep, waking up multiple times during the night, and feeling tired during the day (National Health Service, 2022). The prevalence of sleep problems is high in the general population and can reach 19% in low- and middle-income countries (LMICs) (Koyanagi and Stickley, 2015). Sleep problems are associated with increased risks for chronic physical conditions (e.g., type 2 diabetes (Yao et al., 2021)), poor mental health (e.g., depression (Li et al., 2016)), and higher mortality (Li et al., 2014). Some literature also shows that sleep problems are risk factors for unemployment and decreased work productivity (Kagan et al., 2021). The deleterious effects of sleep problems at the individual and population levels may be particularly pronounced in LMICs, where the treatment and management of sleep problems are frequently insufficient (Aragón-Arreola et al., 2016). In this context, the identification of risk factors for sleep problems in LMICs is of utmost importance.

One potentially important but understudied risk factor for sleep problems, especially in the context of LMICs, is food insecurity, which is defined as the inability or the insufficient ability to access enough food for normal growth and healthy life (Schroeder and Smaldone, 2015). In 2018, approximately 9.2% of the world population was severely food insecure, and this prevalence was higher in LMICs than in high-income countries (HICs) (Roser and Ritchie, 2019). The relationship between food insecurity and sleep problems may be mediated by poor mental health, deficits in nutrients, and immunological dysregulations (Ding et al., 2015).

In the last decade, several studies have focused on the association between food insecurity and sleep (Bermúdez-Millán et al., 2016; Ding et al., 2015; Do et al., 2021; Gyasi et al., 2022; Isaura et al., 2020; Jordan et al., 2016; Liu et al., 2014; Nagata et al., 2019; Troxel et al., 2020; Wang, 2021). A cross-sectional analysis of 223,561 adolescents from 68 countries found a significant association between severe food insecurity and sleep disturbance in 48 of the participating countries, and the odds ratio (OR) ranged from 1.84 (95% CI=1.36-2.32) to 2.03 (95% CI=1.64-2.42) in LMICs (Wang, 2021). Another cross-sectional study, including 10,901 adults from the United States, revealed that very low food security was positively and significantly associated with sleep complaints compared with full food security (OR=1.99, 95% CI=1.36-2.92) (Ding et al., 2015). Finally, in a sample of 785 individuals from that same country, there was a positive association between food insecurity and future shorter actigraphy

assessed sleep duration, poorer sleep efficiency, and poorer subjective sleep quality (Troxel et al., 2020).

Although this previous body of research has advanced the field, most of the studies were conducted in the United States (Bermúdez-Millán et al., 2016; Ding et al., 2015; Do et al., 2021; Liu et al., 2014; Nagata et al., 2019; Troxel et al., 2020), and their results may not be generalizable to other countries, particularly LMICs. In addition, most of the research from LMICs focused on specific populations (e.g., adolescents (Wang, 2021), working-age adults (Isaura et al., 2020), and older adults (Gyasi et al., 2022)), while data were collected from a single country in all studies except one (Wang, 2021). Besides this, little is known about the potential mediating role of mental health factors, such as perceived stress, anxiety, and depression, in the relationship between food insecurity and sleep problems. For example, people with chronic food insecurity may be particularly vulnerable to anxiety (Whittle et al., 2019), and symptoms of anxiety (e.g., excessive worry and apprehensive expectation) have been found to be involved in the genesis of sleep problems (Mellman, 2006). Preliminary data from a small sample of people with type 2 diabetes suggest that these variables partially mediate the relationship between food insecurity and sleep quality (Bermúdez-Millán et al., 2016). However, the generalizability of this study is limited since it was restricted to those with type 2 diabetes. Thus, there is a need for data from general population studies.

Therefore, the aim of this study, including 42,489 adults aged ≥ 18 years from six LMICs (i.e., China, Ghana, India, Mexico, Russia, and South Africa), was to investigate the association between food insecurity and insomnia-related symptoms, and the mediating role of perceived stress, anxiety, and depression in this relationship. It was hypothesized that food insecurity would be associated with higher odds for insomnia-related symptoms, and that a substantial proportion of this association would be explained by perceived stress, anxiety, and depression

Materials & methods

Study participants

This study used data from the Study on Global AGEing and Adult Health (SAGE). Six countries (i.e., China, Ghana, India, Mexico, Russia, and South Africa) participated in the survey between 2007 and 2010. Details on the methodology of the SAGE study have been described in previous literature (Kowal et al., 2012). When the survey was conducted, Ghana was the only country classified as low-income by the World Bank, while China and India were lower middle-income countries. China became an upper middle-income country in 2010. The three other participating countries (i.e., Mexico, Russia, and South Africa) were upper middle-income countries. Nationally representative samples were obtained through a multistage clustered sampling design. Samples included adults aged ≥ 18 years, with those aged ≥ 50 years being oversampled. Face-to-face interviews were conducted by trained interviewers with the use of a standard questionnaire. The questionnaire was translated using a standard procedure to ensure comparability between countries. The survey response rate ranged from 53% in Mexico to 93% in China. Sampling weights that took into account the population structure were constructed based on the reports of the United Nations Statistical Division. Finally, the WHO Ethical Review Committee and local ethics research review boards provided ethical approval, while all participants gave written informed consent.

Insomnia-related symptoms

The following question was used to assess insomnia-related symptoms: “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 five answer options (i.e., “none”, “mild”, “moderate”, “severe”, and “extreme”). Participants were considered to have insomnia-related symptoms if they answered “severe” or “extreme”. The same survey question and definition have been used in previous research (Koyanagi et al., 2014). We focused on severe/extreme sleep problems as these are likely to cause substantial burden for the individual, while the use of extreme categories can potentially increase specificity.

Food insecurity

The following two questions were used to define food insecurity: (a) “In the last 12 months, how often did you ever eat less than you felt you should because there wasn’t enough food?”; and (b) “In the last 12 months, were you ever hungry, but didn’t eat because you couldn’t afford

enough food?”. There were five answer options for each question (i.e., “every month” [coded as 1], “almost every month” [coded as 2], “some months, but not every month” [coded as 3], “only in 1 or 2 months” [coded as 4], and “never” [coded as 5]). These questions are similar to those available in food security questionnaires, such as the U.S. Household Food Security Survey Module and the National Health and Nutrition Examination Survey (NHANES) Food Security Module. Following a previous SAGE publication (Schrock et al., 2017), participants were considered severely food insecure if they answered 1 through 3 to both questions or if they answered 1 to either question. Participants were considered moderately food insecure if they did not fulfil the criteria for severe food insecurity and answered 2 through 4 for either question. Finally, participants were considered food secure if they answered 5 to both questions. Food insecurity was also used as a dichotomous variable in some analyses (i.e., moderate or severe food insecurity versus no food insecurity) to obtain stable estimates or for the sake of interpretability.

Mediators

The mediators (i.e., perceived stress, anxiety, and depression) in the association between food insecurity and insomnia-related symptoms were selected based on previous literature suggesting that these factors can be the consequence of food insecurity and a cause of sleep problems (Alvaro et al., 2013; Bermúdez-Millán et al., 2016; Mellman, 2006; Murphy and Peterson, 2015; Palar et al., 2015; Selvamani and Arokiasamy, 2021; Whittle et al., 2019; Yap et al., 2020). The assessment of past 30-day perceived stress relied on two questions from the Perceived Stress Scale (Cohen et al., 1983). In the present study, scores ranged from two to 10, with higher scores indicating higher stress levels (DeVylder et al., 2016). The following question was used to assess anxiety symptoms: “Overall in the past 30 days, how much of a problem did you have with worry or anxiety?”, with five answer options (i.e., “none”, “mild”, “moderate”, “severe”, and “extreme”). Participants were considered to have anxiety if they answered “severe” or “extreme” (Stubbs et al., 2017). Finally, past 12-month DSM-IV depression was defined using questions from the World Mental Health Survey version of the Composite International Diagnostic Interview (Vancampfort et al., 2018).

Control variables

Control variables were selected based on previous literature (Ding et al., 2015), and included age, sex (i.e., female or male), highest level of education achieved (i.e., ≤primary, secondary, or tertiary), wealth quintile based on income (i.e., poorest, poorer, middle, richer, or richest),

unemployment, marital status (i.e., married/cohabiting, never married, or separated/divorced/widowed), setting (i.e., urban or rural), smoking (i.e., never, past, or current), alcohol consumption, physical activity, body mass index (BMI), and number of chronic physical conditions. Participants were considered unemployed if they had not been engaged in paid work for at least two days in the last seven days. Heavy drinking was defined as the consumption of at least four (female adults) and five drinks (male adults) of any alcoholic beverage per day on at least one day in the past seven days (Romano et al., 2021). Non-heavy drinking corresponded to the consumption of alcohol not meeting these criteria. The Global Physical Activity Questionnaire was used to assess levels of physical activity, and based on conventional cut-offs, physical activity was analyzed as a three-category variable (i.e., low, moderate, and high levels of physical activity) (Bull et al., 2009). BMI was calculated as weight in kilograms divided by height in meters squared based on measured weight and height. BMI was further categorized into four groups: underweight (i.e., $<18.5 \text{ kg/m}^2$), normal weight (i.e., $18.5\text{-}24.9 \text{ kg/m}^2$), overweight (i.e., $25.0\text{-}29.9 \text{ kg/m}^2$), and obesity (i.e., $\geq 30.0 \text{ kg/m}^2$) (World Health Organization, 2000). Data on 11 chronic physical conditions were available: angina, arthritis, asthma, chronic back pain, chronic lung disease, diabetes, edentulism, hearing problem, hypertension, stroke, and visual impairment. **Table S1** (Appendix) provides details on the diagnosis of these conditions. The number of chronic conditions was summed and categorized as 0, 1, and ≥ 2 .

Statistical analysis

The statistical analysis was done with Stata 14.2 (Stata Corp LP, College station, Texas). Differences in sample characteristics were tested by Chi-squared tests and Student's *t*-tests for categorical and continuous variables, respectively. Multivariable logistic regression analysis was conducted to assess the association between food insecurity (i.e., no, moderate, and severe food insecurity; exposure) and insomnia-related symptoms (outcome). Sex-stratified analyses were also performed, as a previous publication showed that this association might differ by sex (Ding et al., 2015). Country-wise analysis was conducted to assess the between-country heterogeneity in the association between any food insecurity (i.e., moderate or severe food insecurity) and insomnia-related symptoms. We used a dichotomous variable on food insecurity for this analysis to obtain stable estimates as the sample size was small in each country. The Higgin's I^2 , which represents the degree of heterogeneity not explained by sampling error, was further calculated. Values of 25%, 50%, and 75% correspond to low,

moderate, and high levels of heterogeneity, respectively (Higgins et al., 2003). An overall estimate was obtained based on country-wise estimates by meta-analysis with random effects.

The role played by perceived stress, anxiety, and depression in the association between any food insecurity and insomnia-related symptoms in the overall sample was further studied using mediation analysis. A dichotomous food insecurity variable was used for this analysis as the aim was to obtain a single estimate for the mediated percentage to ease interpretability. The *kmb* (Karlson Holm Breen) command in Stata was used for the mediation analysis (Breen et al., 2013). Applicable to logistic regression models, this method decomposes the total effect (i.e., unadjusted for the mediator) of a variable into direct and indirect effects. Based on the Karlson Holm Breen method, the percentage of the main association explained by the mediator (i.e., mediated percentage) can also be calculated. Each potential mediator (i.e., perceived stress, anxiety, and depression) was included in the model individually, except for the analysis where all potential mediators were included simultaneously in the model.

All regression analyses, including the mediation analysis, were adjusted for age, sex, education, wealth, unemployment, marital status, setting, smoking, alcohol consumption, physical activity, BMI, number of chronic physical conditions, and country, with the exception of the sex-stratified and country-wise analyses which were not adjusted for sex and country, respectively. Following a previous SAGE publication, adjustment for country was done by including dummy variables for each country in the model (Koyanagi et al., 2014). In order to assess the influence of multicollinearity, we calculated the variance inflation factor (VIF) value for each independent variable. The highest VIF was 2.47, which is much lower than the commonly used cutoff of 10 (O'Brien, 2007), indicating that multicollinearity was unlikely to be a problem in our analyses. Under 2.3% of the data were missing for all the variables included in our study, with the exception of alcohol consumption (4.2%), body mass index (5.8%), and number of chronic physical conditions (4.3%). The sample weighting and the complex study design were taken into account, while missing data were handled using complete-case analysis. Results from the regression analyses are presented as ORs with 95% CIs. Two-sided p -values < 0.050 were considered statistically significant.

Results

There were 42,489 individuals aged ≥ 18 years included in this study (mean [SD] age 43.8 [14.4] years; 50.1% females). The sample sizes of each country were: China, $n=14,813$; Ghana, $n=5,110$; India, $n=11,230$; Mexico, $n=2,756$; Russia, $n=4,355$; and South Africa, $n=4,225$. The prevalence of moderate and severe food insecurity was 6.8% and 5.1%, respectively, while that of insomnia-related symptoms was 4.4%. The prevalence of insomnia-related symptoms varied between countries: China 1.6%, Ghana 3.3%, India 7.0%, Mexico 1.9%, Russia 5.0%, and South Africa 6.8%. The sample characteristics are shown in **Table 1**. The prevalence of female sex, lower levels of education and wealth, unemployment, marital status of separated/divorced/widowed, rural setting, past and current smoking, low physical activity, underweight, obesity, ≥ 2 chronic physical conditions, anxiety, and depression were higher among those with insomnia-related symptoms, while they were also older and with higher levels of perceived stress. The prevalence of insomnia-related symptoms increased linearly with worsening food insecurity status in the overall sample and also sex-stratified samples (**Figure 1**). For example, the prevalence of insomnia-related symptoms was only 3.6% among those without food insecurity, but this increased to 12.6% among those with severe food insecurity in the overall sample. After adjustment for potential confounders, compared to no food insecurity, moderate (OR=1.53, 95% CI=1.11-2.10) and severe food insecurity (OR=2.35, 95% CI=1.56-3.55) were associated with significantly higher odds for insomnia-related symptoms (**Table 2**). Moderate food insecurity was not significantly associated with insomnia related symptoms among females, but among males, it was associated with a significant 2.54 (95% CI=1.48-4.37) times higher odds for insomnia-related symptoms. Country-wise analysis showed that any food insecurity was positively associated with insomnia-related symptoms in all countries (i.e., OR >1) (**Figure 2**). However, a high level of between-country heterogeneity was observed ($I^2=77.7\%$), with the association being weakest in Mexico (OR=1.04; 95% CI=0.52-2.10) and most pronounced in South Africa (OR=7.05; 95% CI=3.58-13.87). The overall estimate based on a meta-analysis with random effects was OR=2.13 (95% CI=1.23-3.67). Finally, mediation analysis showed that anxiety explained the largest proportion of the association between any food insecurity and insomnia-related symptoms (mediated percentage=27.7%), followed by perceived stress (13.5%), and depression (12.5%; **Table 3**). Collectively, these variables explained 43.3% of the association.

Discussion

Main findings

In this study, including more than 42,000 adults from six LMICs, the prevalence of insomnia related symptoms increased with increasing food insecurity. This finding was corroborated in the multivariable logistic regression analysis, with severe food insecurity (versus no food insecurity) being associated with significant 2.35 and 2.74 times higher odds for insomnia-related symptoms in the overall sample and male sample, respectively. Finally, anxiety, perceived stress, and depression individually explained 13%-28% of the relationship, with these three factors collectively explaining 43% of the association. To the best of our knowledge, this is the first multi-country study on this topic in the adult population, while it is the first community-based study to investigate the role played by several mental health factors in the association.

Interpretation of the findings

Several previous studies from LMICs have examined the relationship between food insecurity and sleep problems or other sleep outcomes (e.g., sleep quality and sleep duration) (Gyasi et al., 2022; Isaura et al., 2020; Jordan et al., 2016). For example, a study of 1,201 adults aged ≥ 50 years from Ghana showed that moderate and severe food insecurity were significantly associated with poor sleep quality after adjusting for several potential confounding factors (Gyasi et al., 2022). In another study, including 20,212 middle-aged adults from Indonesia, there was a positive and significant relationship between food insecurity and sleep disturbances (adjusted OR=1.32, 95% CI=1.02-1.70) (Isaura et al., 2020). A third Mexican study, using data from 11,356 individuals aged 18-69 years, revealed that severe food insecurity was associated with sleep duration ≤ 6 hours per night compared with 7-8 hours (OR=1.83, 95% CI=1.37-2.43) (Jordan et al., 2016). The present study not only corroborates these findings obtained in single LMICs, but is also in line with the results of other studies conducted in HICs (Bermúdez-Millán et al., 2016; Ding et al., 2015; Do et al., 2021; Liu et al., 2014; Nagata et al., 2019; Troxel et al., 2020) and the only multi-country study of adolescents from both LMICs and HICs (Wang, 2021). Interestingly, the present findings further show that the significant association between food insecurity and sleep problems exists among adults at the multi-country level in LMICs.

Several hypotheses may be proposed as for the underlying mechanism linking food insecurity and sleep problems. In this study, anxiety, perceived stress, and depression explained 28%, 14%, and 13% of the relationship between food insecurity and insomnia-related symptoms, respectively. The present finding aligns with the preliminary results of a study of 121 Latinos

with type 2 diabetes, as depressive symptoms, anxiety symptoms, and diabetes distress (i.e., emotional distress from living with diabetes) significantly mediated the association between household food insecurity and suboptimal sleep quality (Bermúdez-Millán et al., 2016). Interestingly, previous research has found that food insecurity is longitudinally associated with anxiety, potentially via negative feelings and malnutrition caused by chronic low intakes of vegetables and fruits (Whittle et al., 2019), while anxiety is a risk factor for future sleep problems (Alvaro et al., 2013; Mellman, 2006). Several anxiety disorders (e.g., generalized anxiety disorder and post-traumatic stress disorder) have bidirectional relationships with sleep disturbances, which may involve hypermetabolism of multiple brain regions (e.g., locus coeruleus, limbic system, and thalamus), dopaminergic hypoactivity, and changes in the strength of binding of γ -aminobutyric acid (GABA) receptors (Chellappa and Aeschbach, 2022). The literature has also reported a strong relationship between food insecurity and perceived stress, and this relationship may be explained by multiple factors such as socioeconomic disparity, poor diet, and insufficient social support (Selvamani and Arokiasamy, 2021). Meanwhile, stress has been identified as a predictor of decreased sleep quantity, with hyperactivation of the hypothalamic-pituitary-adrenal axis and pre-sleep cognitive arousals likely playing a major role in the association (Yap et al., 2020). Finally, there is also some data showing a longitudinal relationship between food insecurity and depressive symptoms, potentially via a feeling of low self-efficacy, worries about physical health, and deficit in nutrients (e.g., fatty acids, vitamin B9, and vitamin B12) (Palar et al., 2015). In turn, depressive symptoms can lead to poor sleep health through the dysregulation of monoamines and hypercortisolemia (Murphy and Peterson, 2015). Taking these results together, impaired mental health likely plays an essential role in the association between food insecurity and sleep problems.

It is also important to note that since perceived stress, anxiety, and depression explained around 43% of the relationship, other factors are also likely to be involved. For example, food insecurity is a risk factor for deficiency in multiple nutrients such as vitamins, calcium, and zinc (Zarei et al., 2021), while nutrient deficiency (e.g., vitamin D deficiency) could have a deleterious impact on sleep via chronic pain and immunological dysregulations (Gao et al., 2018). Besides, food insecurity is associated with increased inflammation (Gowda et al., 2012), and inflammation and sleep problems are intimately related, although the mechanisms of the association remain insufficiently understood up until now (Simpson and Dinges, 2007). Sleep environment should also be considered when investigating the effects of food insecurity on

insomnia-related symptoms as a confounding factor. Indeed, sleep environment is correlated with both diet (St-Onge et al., 2019) and sleep problems (Johnson et al., 2018).

Our study also suggests that there may be sex differences in the relationship between food insecurity and insomnia-related symptoms, as moderate food insecurity was positively associated with insomnia-related symptoms in men but not women. While the mechanism underlying this sex difference is unknown, some data indicate that sex hormones (i.e., estrogen and testosterone) may influence quality of sleep (Mong and Cusmano, 2016), and these hormones may play a differential role in the association between food insecurity and insomnia-related symptoms by sex.

Interestingly, there was high level of between-country heterogeneity in the association between any food insecurity and insomnia-related symptoms, with ORs ranging from 1.04 (95% CI=0.52-2.10) in Mexico to 7.05 (95% CI=3.58-13.87) in South Africa. This result suggests that the association between food insecurity and insomnia-related symptoms may involve factors that are country-specific (e.g., level of nutrient deficiency caused by food insecurity and availability of treatments for sleep problems). Besides, differences in the severity of food insecurity may exist between countries, which could explain the high between-country heterogeneity observed in this study. Finally, sleep and its perception are likely impacted by cultural factors, which vary between different countries and regions of the world (Knutson, 2013).

Public health implications and directions for future research

Our study showed that food insecurity is significantly associated with insomnia-related symptoms among adults in LMICs. Although causality or temporal associations cannot be determined because of the cross-sectional nature of the study, our study results suggest that interventions to reduce food insecurity itself or the potential mediators identified in our study (i.e., anxiety, perceived stress, and depression) among those with food insecurity may help reduce sleep problems in LMICs. A recent Cochrane review indicates that unconditional cash transfers can improve food security in these countries, whereas the effectiveness of other interventions (e.g., food vouchers and social support) remains debated (Duraio et al., 2020). It is also critical to manage the negative impact of food insecurity on mental health. This aim can be achieved by implementing mental health policies and laws, providing financial resources, planning specialized services, and promoting adequate training in low- and middle-income

regions (Rathod et al., 2017). Finally, future longitudinal research on this topic from LMICs is necessary to determine direction of associations and provide further insight into potential causality.

Strengths and limitations

The strengths of this study are the large sample size and the use of nationally representative data from six LMICs. Nonetheless, the study findings should be interpreted in light of several limitations. First, data were collected between 2007 and 2010, and the association between food insecurity and insomnia-related symptoms may have changed in the last decade. Second, food insecurity was assessed with two questions only, and additional questions would have allowed for a more accurate measure of food insecurity. Third, there is no standardized definition for sleep problems, and the definition used in the present study focused on insomnia related symptoms (i.e., falling asleep, waking up frequently during the night, and waking up too early in the morning). It is important to note that the prevalence of insomnia-related symptoms was relatively low in the sample due to the use of extreme categories to define this condition. Thus, the use of other criteria would have led to higher prevalence. Fourth, there was no data on sleep environment (e.g., darkness, noise, and temperature), despite the fact that sleep environment may be associated with both food insecurity and insomnia-related symptoms.

Fifth, this study only included adults living in households, and the results may, therefore, not be generalized to homeless or institutionalized people. Finally, this research was of cross-sectional nature, and thus, causality of the relationship could not be investigated.

Conclusion

In this study of approximately 42,500 adults aged ≥ 18 years from six LMICs (i.e., China, Ghana, India, Mexico, Russia, and South Africa), there was a positive and significant association between food insecurity and insomnia-related symptoms, while anxiety, perceived stress, and depression collectively explained approximately 43% of the relationship. Future longitudinal studies are needed to corroborate or invalidate these results, while future research should also identify other mediators involved in the association between food insecurity and sleep problems.

References

- Alvaro, P.K., Roberts, R.M., Harris, J.K. A Systematic Review Assessing Bidirectionality between Sleep Disturbances, Anxiety, and Depression. *Sleep*, 2013, 36: 1059–1068.
- Aragón-Arreola, J.F., Moreno-Villegas, C.A., Armienta-Rojas, D.A., De la Herrán-Arita, A.K. An insight of sleep disorders in Africa. *eNeurologicalSci*, 2016, 3: 37–40.
- Bermúdez-Millán, A., Pérez-Escamilla, R., Segura-Pérez, S., et al. Psychological Distress Mediates the Association between Food Insecurity and Suboptimal Sleep Quality in Latinos with Type 2 Diabetes Mellitus. *J Nutr*, 2016, 146: 2051–2057.
- Breen, R., Karlson, K.B., Holm, A. Total, Direct, and Indirect Effects in Logit and Probit Models. *Sociological Methods & Research*, 2013, 42: 164–191.
- Bull, F.C., Maslin, T.S., Armstrong, T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *J Phys Act Health*, 2009, 6: 790–804.
- Chellappa, S.L., Aeschbach, D. Sleep and anxiety: From mechanisms to interventions. *Sleep Med Rev*, 2022, 61: 101583.
- Cohen, S., Kamarck, T., Mermelstein, R. A global measure of perceived stress. *J Health Soc Behav*, 1983, 24: 385–396.
- DeVylder, J.E., Koyanagi, A., Unick, J., Oh, H., Nam, B., Stickley, A. Stress Sensitivity and Psychotic Experiences in 39 Low- and Middle-Income Countries. *Schizophr Bull*, 2016, 42: 1353–1362.
- Ding, M., Keiley, M.K., Garza, K.B., Duffy, P.A., Zizza, C.A. Food insecurity is associated with poor sleep outcomes among US adults. *J Nutr*, 2015, 145: 615–621.
- Do, E.K., Bowen, G.A., Ksinan, A.J., Adams, E.L., Fuemmeler, B.F. Sleep, Food Insecurity, and Weight Status: Findings from the Family Life, Activity, Sun, Health, and Eating Study. *Child Obes*, 2021, 17: 125–135.
- Durao, S., Visser, M.E., Ramokolo, V., et al. Community-level interventions for improving access to food in low- and middle-income countries. *Cochrane Database Syst Rev*, 2020, 7: CD011504. 9
- Gao, Q., Kou, T., Zhuang, B., Ren, Y., Dong, X., Wang, Q. The Association between Vitamin D Deficiency and Sleep Disorders: A Systematic Review and Meta-Analysis. *Nutrients*, 2018, 10: E1395.
- Gowda, C., Hadley, C., Aiello, A.E. The association between food insecurity and inflammation in the US adult population. *Am J Public Health*, 2012, 102: 1579–1586.

- Gyasi, R.M., Asamoah, E., Gyasi-Boadu, N., Zornu, O., Asiki, G., Phillips, D.R. Food insecurity and sleep quality among older adults: Findings from a population-based study in Ghana. *Maturitas*, 2022, 157: 27–33.
- Higgins, J.P.T., Thompson, S.G., Deeks, J.J., Altman, D.G. Measuring inconsistency in meta-analyses. *BMJ*, 2003, 327: 557–560.
- Isaura, E.R., Chen, Y.-C., Su, H.-Y., Yang, S.-H. The Relationship between Food Security Status and Sleep Disturbance among Adults: A Cross-Sectional Study in an Indonesian Population. *Nutrients*, 2020, 12: 3411. 39
- Johnson, D.A., Billings, M.E., Hale, L. Environmental Determinants of Insufficient Sleep and Sleep Disorders: Implications for Population Health. *Curr Epidemiol Rep*, 2018, 5: 61–69.
- Jordan, M.L., Perez-Escamilla, R., Desai, M.M., Shamah-Levy, T. Household Food Insecurity and Sleep Patterns Among Mexican Adults: Results from ENSANUT-2012. *J Immigr Minor Health*, 2016, 18: 1093–1103.
- Kagan, R., Shiozawa, A., Epstein, A.J., Espinosa, R. Impact of sleep disturbances on employment and work productivity among midlife women in the US SWAN database: a brief report. *Menopause*, 2021, 28: 1176–1180.
- Knutson, K.L. Sociodemographic and cultural determinants of sleep deficiency: implications for cardiometabolic disease risk. *Soc Sci Med*, 2013, 79: 7–15.
- Kowal, P., Chatterji, S., Naidoo, N., et al. Data resource profile: the World Health Organization Study on global AGEing and adult health (SAGE). *International Journal of Epidemiology*, 2012, 41: 1639–1649.
- Koyanagi, A., Garin, N., Olaya, B., et al. Chronic conditions and sleep problems among adults aged 50 years or over in nine countries: a multi-country study. *PLoS One*, 2014, 9: e114742.
- Koyanagi, A., Stickley, A. The Association between Sleep Problems and Psychotic Symptoms in the General Population: A Global Perspective. *Sleep*, 2015, 38: 1875–1885.
- Li, L., Wu, C., Gan, Y., Qu, X., Lu, Z. Insomnia and the risk of depression: a meta-analysis of prospective cohort studies. *BMC Psychiatry*, 2016, 16: 375.
- Li, Y., Zhang, X., Winkelman, J.W., et al. Association between insomnia symptoms and mortality: a prospective study of U.S. men. *Circulation*, 2014, 129: 737–746.
- Liu, Y., Njai, R.S., Greenlund, K.J., Chapman, D.P., Croft, J.B. Relationships between housing and food insecurity, frequent mental distress, and insufficient sleep among adults in 12 US States, 2009. *Prev Chronic Dis*, 2014, 11: E37.

Mellman, T.A. Sleep and anxiety disorders. *Psychiatr Clin North Am*, 2006, 29: 1047–1058; abstract x.

Mong, J.A., Cusmano, D.M. Sex differences in sleep: impact of biological sex and sex steroids. *Philos Trans R Soc Lond B Biol Sci*, 2016, 371: 20150110.

Murphy, M.J., Peterson, M.J. Sleep Disturbances in Depression. *Sleep Med Clin*, 2015, 10: 17–23.

Nagata, J.M., Palar, K., Gooding, H.C., et al. Food Insecurity Is Associated With Poorer Mental Health and Sleep Outcomes in Young Adults. *J Adolesc Health*, 2019, 65: 805–811. National Health Service Sleep problems and insomnia, <https://www.nhs.uk/every-mindmatters/mental-health-issues/sleep/>.

O'brien, R.M. A Caution Regarding Rules of Thumb for Variance Inflation Factors. *Qual Quant*, 2007, 41: 673–690.

Palar, K., Kushel, M., Frongillo, E.A., et al. Food Insecurity is Longitudinally Associated with Depressive Symptoms Among Homeless and Marginally-Housed Individuals Living with HIV. *AIDS Behav*, 2015, 19: 1527–1534.

Rathod, S., Pinninti, N., Irfan, M., et al. Mental Health Service Provision in Low- and Middle Income Countries. *Health Serv Insights*, 2017, 10: 1178632917694350.

Romano, E., Ma, R., Vancampfort, D., et al. Multimorbidity and obesity in older adults from six low- and middle-income countries. *Prev Med*, 2021, 153: 106816.

Roser, M., Ritchie, H. Hunger and Undernourishment, <https://ourworldindata.org/hunger-and-undernourishment>.

Schrock, J.M., McClure, H.H., Snodgrass, J.J., et al. Food insecurity partially mediates associations between social disadvantage and body composition among older adults in india: Results from the study on global AGEing and adult health (SAGE). *Am J Hum Biol*, 2017, 29.

Schroeder, K., Smaldone, A. Food Insecurity: A Concept Analysis. *Nurs Forum*, 2015, 50: 274–284.

Selvamani, Y., Arokiasamy, P. Association between food insecurity and perceived stress among older adults (50+) in six low- and middle-income countries. *Aging Ment Health*, 2021, 1–9.

Simpson, N., Dinges, D.F. Sleep and inflammation. *Nutr Rev*, 2007, 65: S244–252.

St-Onge, M.-P., Pizinger, T., Kovtun, K., RoyChoudhury, A. Sleep and meal timing influence food intake and its hormonal regulation in healthy adults with overweight/obesity. *Eur J Clin Nutr*, 2019, 72: 76–82.

Stubbs, B., Koyanagi, A., Hallgren, M., et al. Physical activity and anxiety: A perspective from the World Health Survey. *J Affect Disord*, 2017, 208: 545–552.

Troxel, W.M., Haas, A., Ghosh-Dastidar, B., et al. Food Insecurity is Associated with Objectively Measured Sleep Problems. *Behav Sleep Med*, 2020, 18: 719–729.

Vancampfort, D., Stubbs, B., Mugisha, J., Firth, J., Schuch, F.B., Koyanagi, A. Correlates of sedentary behavior in 2,375 people with depression from 6 low- and middle-income countries. *J Affect Disord*, 2018, 234: 97–104.

Wang, Q. Food Insecurity and Sleep Disturbance Among 223,561 Adolescents: A Multi Country Analysis of Cross-Sectional Surveys. *Front Public Health*, 2021, 9: 693544.

Whittle, H.J., Sheira, L.A., Wolfe, W.R., et al. Food insecurity is associated with anxiety, stress, and symptoms of posttraumatic stress disorder in a cohort of women with or at risk of HIV in the United States. *J Nutr*, 2019, 149: 1393–1403.

World Health Organization Obesity : preventing and managing the global epidemic : report of a WHO consultation. , Geneva , 2000.

Yao, W., Luo, J., Yu, X., Jiang, W., Zhang, D. Insomnia symptoms are associated with an increased risk of type 2 diabetes mellitus among adults aged 50 and older. *Sleep Breath*, 2021,.

Yap, Y., Slavish, D.C., Taylor, D.J., Bei, B., Wiley, J.F. Bi-directional relations between stress and self-reported and actigraphy-assessed sleep: a daily intensive longitudinal study. *Sleep*, 2020, 43: zsz250.

Zarei, M., Qorbani, M., Djalalinia, S., et al. Food Insecurity and Dietary Intake Among Elderly Population: A Systematic Review. *Int J Prev Med*, 2021, 12: 8.