Systematic Review and Meta-Analysis

Food insecurity is associated with the sleep quality and quantity in adults: a systematic review and meta-analysis

Seyadeh Narges Mazloomi[1,2], Sepide Talebi[3], Maryam Kazemi[4],
Seyed Mojtaba Ghoreishy[3], Seyedeh Parisa Moosavian[5], Parsa Amirian[6],
Hamed Mohammadi[3], Saeedeh Nouri-Majd[7], Wolfgang Marx[8] (iD),
Mohammad Ali Hojjati Kermani[9] and Sajjad Moradi[10],* (iD)

[1]The Health of Plant and Livestock Products Research Center, Mazandaran University of Medical Sciences, Sari, Iran:
[2]Food and Drug Administration, Mazandaran University of Medical Sciences, Sari, Iran: [3]Department of Clinical
Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran: [4]Hilda and
J. Lester Gabrilove Division of Endocrinology, Diabetes, and Bone Disease, Department of Medicine, Icahn School of
Medicine at Mount Sinai, New York, NY, USA: [5]Department of Community Nutrition, Vice-Chancellery for Health,
Shiraz University of Medical Sciences, Shiraz, Iran: [6]General Practitioner, Kermanshah University of Medical Sciences
(KUMS), Kermanshah, Iran: [7]Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran
University of Medical Sciences, Tehran, Iran: [8]Deakin University, IMPACT – the Institute for Mental and Physical Health
and Clinical Translation, School of Medicine, Barwon Health, Geelong, Australia: [9]Clinical Tuberculosis and
Epidemiology Research Center, National Research Institute of Tuberculosis and Lung Diseases (NRITLD), Masih
Daneshvari Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran: [10]Nutritional Sciences Department,
School of Nutritional Sciences and Food Technology, Kermanshah University of Medical Sciences, Kermanshah, Iran

Abstract

Objective: We evaluated associations between food insecurity (FI) and the quality
and quantity of sleep in adults ($\geq$18 years).
Design: The current study represented a systematic review and meta-analysis of
observational studies.
Setting: Databases of PubMed, Scopus, Embase and Web of Science were searched
from inception until 6 June 2022. Meta-analyses were conducted using random-
effects models, and effect sizes were reported as OR and 95 % CI.
Participants: Data from ten eligible observational studies, including 83 764 partici-
pants, were included.
Results: FI was associated with an increased risk of poor sleep quality (OR = 1·45; 95 %
CI (1·24, 1·70), $I^2 = 95$, $P < 0.001$, n 7). Besides, subgroup analysis showed increased
risk of poor sleep quality corresponding to the severity of FI across mild (OR = 1·31;
95 % CI (1·16, 1·48), $I^2 = 0$ %, $P < 0.001$, n 5), moderate (OR = 1·49; 95 % CI (1·32,
1·68), $I^2 = 0$ %, $P < 0.001$, n 5) and severe (OR = 1·89; 95 % CI (1·63, 2·20), $I^2 = 0$ %,
$P < 0.001$, n 5) levels. Similarly, subgroup analysis by sleep problems showed that
FI was associated with an increased the risk of trouble falling asleep (OR = 1·39;
95 % CI (1·05, 1·83), $I^2 = 91$ %, $P = 0.002$, n 3) and trouble staying asleep
(OR = 1·91; 95 % CI (1·37, 2·67), $I^2 = 89$ %, $P < 0.001$, n 3). Moreover, FI was associated
with the odds of shorter (OR = 1·14; 95 % CI (1·07, 1·21), $I^2 = 0$ %, $P < 0.001$, n 4) and
longer sleep duration (OR = 1·14; 95 % CI (1·03, 1·26), $I^2 = 0$ %, $P = 0.010$, n 4).
Conclusions: Collective evidence supports that FI is associated with poor sleep quality
and quantity in adults. Preventative and management strategies that address FI may
provide health benefits beyond improving nutritional status per se.

Corresponding author: Email sajadmoradi9096@gmail.com

Food insecurity (FI) is characterised by the US Department of Agriculture as limited or uncertain access to nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways due to limited financial resources[1]. FI represents a staggering global burden[2]. The prevalence of moderate or severe FI has substantially increased from 8·3 % in 2014 to 25·9 % in 2020, with a projected two billion individuals at risk of hunger[3]. The condition is associated with an increased risk of morbidity, including type 2 diabetes[4], CVD[5], anaemia[6], metabolic syndrome[7,8], stunting[8], mental disorders[9] and mortality[10], highlighting the need for preventative and management strategies.

Sleep plays a significant role in the physical and mental health status[11,12]. Many factors are known to affect the quality and quantity of sleep, including ageing[13], chronic diseases[14], obesity[15], occupational stress[16], poor sleep environment[17], smoking[18], excessive caffeine[19], alcohol[20] and drinking consumption. Similarly, FI may contribute to impaired sleep behaviours[21], albeit the evidence is less conclusive.

In general, available studies have reported positive associations between FI and poor sleep quality; however, results are less consistent on select sleep health outcomes, including sleep quality and duration[22–27]. To that end, Ding et al.[22] and Jordan et al.[25] have reported associations between FI and poor sleep quality across the mild to severe status. However, Grandner et al.[28] showed only extreme levels of FI are related to poor sleep quality, unlike mild levels. Consistently, data on associations between FI and sleep duration are mixed. Troxel et al.[29] reported that higher levels of FI were associated with a greater risk of short or long sleep duration compared with normal sleep duration (7–9 h). Similarly, Narcisse et al.[30] and Jordan et al.[25] showed that FI is associated with short sleep duration. In contrast, they reported a lack of association between FI and long sleep duration[25,30]. Conversely, Whinnery et al.[31] exhibited FI is associated with both short and long sleep duration. Collectively, little can be concluded on the direction and magnitude of the relationship between FI and sleep behaviours.

To our knowledge, no meta-analysis has pooled evidence on the relationship between FI and sleep behaviours, despite a clear need. To address this knowledge gap, we conducted a systematic review and meta-analysis of observational studies to delineate associations between FI and the quality and quantity of sleep in adults (≥18 years). We also comprehensively evaluated factors that may influence these associations, including the severity of FI and biological and socio-demographic characteristics of study populations (e.g. age, sex, BMI, race, ethnicity, mental health, education and income status).

Methods

Systematic search and study selection

The work presented herein was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[32]. The study protocol was registered at the PROSPERO (Prospective Register of Systematic Reviews; registration identifier: CRD42021275645). A comprehensive literature search was conducted using the databases of PubMed, Scopus, Web of Science and Embase from inception until 6 June 2022. The search was performed using following medical subject heading (MeSH) and defined search terms without any language or date restrictions: (('Food Supply'[Mesh] OR 'Food Supply'[Title/Abstract] OR 'Food Supplies'[Title/Abstract] OR 'FI'[Title/Abstract] OR 'Food Insecurities'[Title/Abstract] OR 'Food security'[Title/Abstract] OR 'Food securities'[Title/Abstract]) AND ('Sleep'[Mesh] OR 'Sleep'[tiab] OR 'insomnia'[tiab] OR 'insomnias'[tiab] OR 'sleep problems'[tiab] OR 'sleep quality'[tiab] OR 'sleep duration'[tiab] OR 'sleep deprivation'[tiab] OR 'sleep disturbance'[tiab] OR 'sleep disorders'[tiab]) (see online Supplemental Table 1). Also, the references of retrieved records were evaluated manually to identify relevant citations for inclusion in our literature search.

Eligibility criteria

Studies were included in the final analysis if they: (1) were observational (cross-sectional, cohort and case–control); (2) were conducted on adults (≥18 years); and (3) reported effect estimates in the form of OR, relative risk, or hazard ratio and with corresponding 95 % CI on associations between FI and sleep quality across short (≤6 h) or long (≥9 h) durations.

Exclusion criteria were studies: (1) that conducted on children or adolescents (<18 years); (2) that had insufficient data for inclusion in our analyses; and (3) that had with inappropriate designs, including interventional studies, reviews, letters, editorials, conference proceedings, notes or surveys.

Study selection

The titles and abstracts of all identified records in our literature search were assessed independently by two authors (SM and M-AH-K), followed by a full-text review of eligible records. All discrepancies were resolved by consensus with a third investigator (HM).

Data collection

Extracted data for each included study were as follows: (1) the first author's name; (2) study publication year; (3) databases used; (4) study design; (5) study country of origin; (6) study sample size; (7) biological and socio-demographic

Fig. 1 PRISMA flow diagram of the study

characteristics of study populations (e.g. age, sex, BMI, race, ethnicity, mental health, education and income status where available); (8) level of FI severity; (9) assessment methods for FI and sleep behaviours; (10) relevant effect estimates; (11) study main findings; and (12) any adjusted analyses. Two investigators (SM and HM) independently extracted data for all included records using a standard information extraction template. Data extraction was reviewed by all other authors (S-NM, ST, MK, S-MG, S-PM, PA, SN-M and WM) for any potential extraction error.

Quality assessment

Two investigators (SM and HM) independently examined the quality of each included study using the Newcastle–Ottawa scale[33]. The method of quality evaluation has been formerly described[6,12].

Statistical analysis

All statistical tests were conducted using STATA (version 14.0; Stata Corp.). To analyse associations between FI and sleep behaviours, fully adjusted risk estimates for poor sleep quality and short or long sleep duration were pooled. Pooled OR and 95 % CI were estimated using a weighted random-effects model per the DerSimonian–Laird approach[34]. The heterogeneity among the studies was examined by the Cochran Q and I^2 statistics (I^2 = (Q-df)/ Q × 100 %; I^2 < 25 %, no heterogeneity; I^2 = 25–50 %, moderate heterogeneity; I^2 = 50–75 %, considerable heterogeneity, I^2 > 75 %, extreme heterogeneity). The heterogeneity was considered significant if the Q statistic had $P < 0{\cdot}1$ or $I^2 > 50$ %. To identify the sources of heterogeneity, subgroup analyses were conducted based on FI levels (mild, moderate and severe)[35], sleep problems (trouble falling asleep and difficulty staying asleep) and country (USA and Mexico). We also performed subgroup analyses based on age (<50 and ≥50 years), ethnicity/race (mixed and Latino) and number of participants (<4000 and >4000). Our subgroup analyses were justified based on eight recommended criteria of the Instrument to Evaluate the Credibility of Effect Modification Analyses (ICEMAN)[36]. We also performed meta-regression analyses to evaluate the link between the risk of sleep quality or quantity and heterogeneity between studies. Further, we

Table 1 Summary of studies included in the meta-analysis

First author (year)	Database study design/country	Subjects: age (year) population size sex	Race/ ethnicity	Level of food insecurity	Measure of food insecurity	Measure of sleep assessment	OR (95 % CI)	Main findings	Adjusted variables	Quality score
Grandner et al. (2013)	The 2007–2008 NHANES /Cross-sectional/USA	≥ 18 years n 4081 (51·95 % male and 48·05 % female)	Mixed	Household	USDA	Specific survey question	Sleep quality	Household food insecurity was associated with poor sleep quality	Age, sex, race/ethnicity, education, income, BMI, general health, physical health, immigration status and marital status	+7/10
Ding et al. (2014)	2005–2006, 2007–2008 and 2009–2010 cycles of NHANES/cross-sectional/USA	≥ 22 years n 15 961 (35·31 % male and 64·69 % female)	Mixed	Household	USDA	Specific survey question	Sleep quality	Household food insecurity was associated with poor sleep quality	Poverty income ratio, BMI, household size, race/ethnicity, education level, marital status, work schedule, poor mental health, general health condition, smoking status, alcohol consumption and menopause status	+8/10
Whinnery et al. (2014)	The 2007–2008 NHANES /cross-sectional/USA	≥ 18 years n 4850 (48·3% male and 51·6 % female)	Mixed	Household	USDA	Specific survey question	Sleep duration	Those with mild food insecurity were more likely to have short sleep durations.	Overall health, probable insomnia and probable sleep apnoea	+7/10
Jordan et al. (2016)	ENSANUT-2012/ cross-sectional/ Mexico	≥ 18 years n 11 356 (44·9% male and 55·1 % female)	Latina	Household	ELCSA	Specific survey question	Sleep duration and quality	Household food insecurity was associated with inadequate sleep duration and poor sleep quality among Mexican adults.	Age, sex, area of residence, household size, socioeconomic and BMI	+8/10
Narcisse et al. (2019)	Hawaiian and other Pacific Islanders (NHPI)/cross-sectional/USA	≥ 18 years n 12 619 (46·1% male and 53·9 % female)	Mixed	Household	Survey	Specific survey question	Sleep duration and quality	Food insecurity was associated with sleep quality and quantity	Age, sex, poverty level, education, employment and marital status	+8/10
Troxel et al. (2019)	Cross-sectional/USA	≥ 18 years n 785 (23·4% male and 76·4 % female)	Mixed	Household	USDA	Specific survey question	Sleep duration	Greater food insecurity was associated with a greater likelihood of short and long sleep	Age, sex, education, marital/ cohabitation status, annual household income, presence of children in the home, use of Supplemental Nutrition Assistance Program (SNAP), length of residence in the neighbourhood, BMI and neighbourhood type	+8/10
Zein et al. (2019)	Cross-sectional/USA	≥ 18 years n 855 (31·2% male and 68·8 % female)	Mixed	Household	USDA	PSQI	Sleep quality	Food insecurity had significantly higher odds of poor sleep quality	Age, sex, race/ethnicity, place of residence, meal plan, employment, Pell grant status, university and parental education	+9/10
	National Longitudinal Study	≥ 18 years n 14 786 (51 %	Mixed	Household	USDA		Sleep quality		Age, sex, race/ethnicity, education, income, household	+8/10

Table 1 Continued

First author (year)	Database study design/country	Subjects: age (year) population size sex	Race/ ethnicity	Level of food inse-curity	Measure of food insecurity	Measure of sleep assessment	OR (95 % CI)	Main findings	Adjusted variables	Quality score
Nagata *et al.* (2019)	of Adolescent to Adult Health/ cross-sectional/ USA	male and 49 % female)				Specific survey question		Food insecurity was associ-ated with poorer sleep out-comes	size, BMI, smoking, alcohol and receipt of public assis-tance	
Hagedorn *et al.* (2021)	Cross-sectional/USA	≥ 18 years n 17 686 (25·1% male and 74·9 % female)	Mixed	Household	USDA	PSQI	Sleep quality	Food-insecure students had higher adjusted odds of hav-ing poor sleep quality	Age, sex, race, BMI, living on or off-campus, having dependents, having a dis-ability, and having restless leg syndrome symptoms	+9/10

KNHANES, Korea National health and nutritional examination survey; ENSANUT-2012, The 2012 Mexican national health and nutrition survey; ELCSA, The Latin American and Caribbean food security scale; PSQI, Pittsburgh sleep quality index; IFLS5, Indonesian family life survey; PROMIS, patient-reported outcomes measurement information system; CES-D, epidemiologic studies – depression.

performed sensitivity analyses by removing each study and recalculating the overall effect size to determine whether an individual study exerted undue influence. Funnel plots and results of Begg's and Egger's tests were used to assess pub-lication bias. Results were considered significant at $P < 0.05$.

Results

The systematic search resulted in 651 records (Fig. 1), of which 318 records were screened after removing dupli-cates. Of these 318 records, 302 were excluded because they did not meet our inclusion criteria, resulting in nine-teen eligible studies for full-text evaluation[22–31,37–42]. Of these nineteen studies, ten were excluded because they were conducted on children[40] or adolescents[43], provided insufficient data for inclusion in our analyses[37–39,41,42,44,45], or used variable domains to measure FI[24]. Together, nine eligible studies (*n* 83 764)[22,23,25–31] were included in our study (Fig. 1).
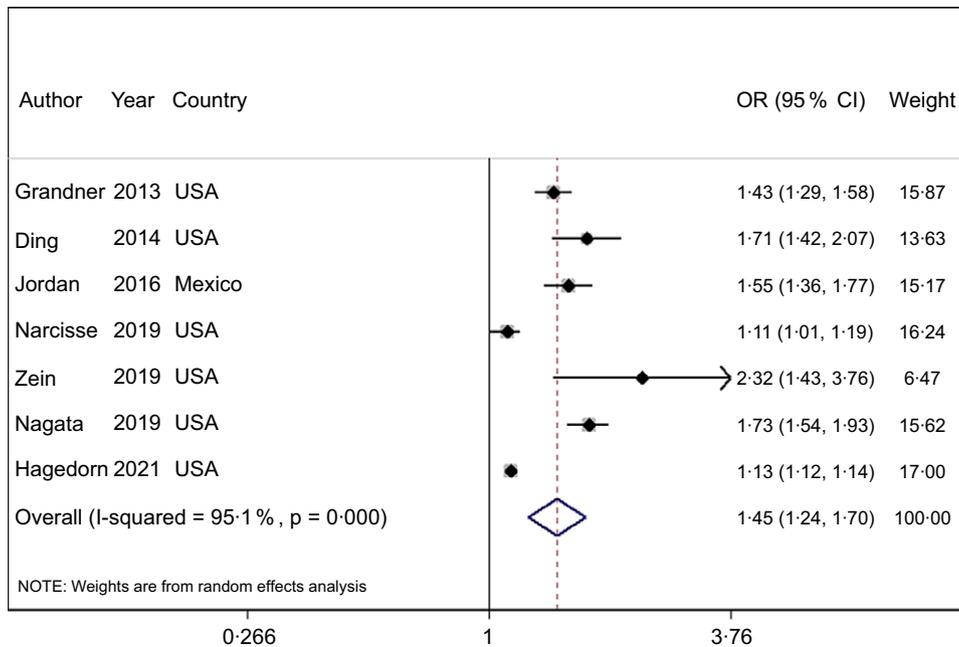
All included studies had a cross-sectional design (Table 1) and were published between 2013 and 2021 and conducted in the USA[22,23,26–31] and Mexico[25]. OR on the link between FI and quality and quantity of sleep were pooled across these nine studies for meta-analyses. Seven studies assessed poor sleep quality risk (*n* 47 439), and four reported sleep duration risk (*n* = 29 583).

Results of the study quality assessment for each study are shown in Table 1. Briefly, quality assessments revealed that seven studies had high quality[22,23,25–27,29,30] and two had medium quality[28,31] (Table 1).

Sleep quality

FI was associated with an increased risk of poor sleep qual-ity in adults (OR = 1·45; 95 % CI (1·24, 1·70), $P < 0.001$, *n* 7; Fig. 2). Studies were highly heterogenous ($I^2 = 95$ %, $P < 0.001$).

Subgroup analysis showed increased risk of poor sleep quality corresponding to the severity of FI across mild (OR = 1·31; 95 % CI (1·16, 1·48), $I^2 = 0$ %, $P < 0.001$, *n* 5), moderate (OR = 1·49; 95 % CI (1·32, 1·68), $I^2 = 0$ %, $P < 0.001$, *n* 5) and severe (OR = 1·89; 95 % CI (1·63, 2·20), $I^2 = 0$ %, $P < 0.001$, *n* 5) levels (Table 2). Similarly, subgroup analysis by sleep problems showed that FI was associated with an increased the risk of trouble falling asleep (OR = 1·39; 95 % CI (1·05, 1·83), $I^2 = 91$ %, $P = 0.002$, *n* 3) and trouble staying asleep (OR = 1·91; 95 % CI (1·37, 2·67), $I^2 = 89$ %, $P < 0.001$, *n* 3; Table 2). Also, subgroup analysis based on country revealed that FI was associated with an increased the risk of poor sleep quality across studies conducted within (OR = 1·44; 95 % CI (1·22, 1·70), $I^2 = 95$ %, $P < 0.001$, *n* 6) or out of (OR = 1·55; 95 % CI (1·36, 1·77), *n* 1) USA.

Public Health Nutrition

Fig. 2 Forest plot showing the OR and 95 % CI of the association between food insecurity and the risk of poor sleep quality

To further explore the sources of heterogeneity, meta-regression analyses were conducted to identify any influence of FI degree, sleep problems, age, race/ethnicity, study sample size and adjusted risk estimates across different exposure categories (Table 3). Heterogeneity was decreased following meta-regression analyses based on FI levels ($P = 0.003$, $I^2 = 0$ %; Table 3 and see online Supplemental Fig. 1). However, sleep problems, age, race/ethnicity, number of participants, and studies that controlled for sex, BMI, mental, education, and income did not explain the sources of heterogeneity.

Sleep quantity

FI was associated with an increased risk of short (OR = 1·14; 95 % CI (1·07, 1·21), $P < 0.001$, n 4) or long (OR = 1·14; 95 % CI (1·03, 1·26), $P = 0.010$, n 4) and sleep duration (Figs. 3 and 4, respectively), and studies were homogenous (All: $I^2 = 0$ %; All: $P \geq 0.05$). In addition, subgroup analysis showed that a severe level of FI is associated with an increased risk of short sleep duration (OR = 1·59; 95 % CI (1·16, 2·18), $I^2 = 46$ %, $P = 0.004$, n 2; Table 2). In contrast, meta-regression analyses based on pooled FI levels, age, race and study size could not explain the sources of heterogeneity (All: $P > 0.05$, Table 3 and see online Supplemental Figs. 2 and 3).

Sensitivity analysis and publication bias

Sensitivity analysis revealed that the pooled effect estimates were not affected by any single study included in our analyses. The Egger's test ($P = 0.01$) revealed a publication bias for studies assessing the relationship between FI and the risk of poor sleep quality. However, the bias was not

evident using Begg's test results ($P = 0.71$) or a symmetric funnel plot (Fig. 5(a)). Further, we observed no publication bias in studies evaluating the link between FI and short ($P = 0.30$ for Begg's test and $P = 0.39$ for Egger's test; Fig. 5(b)) and long ($P = 0.49$ for Begg's test and $P = 0.73$ for Egger's test; Fig. 5(c)) sleep duration.

Discussion

Few studies have examined the relationship between FI and non-nutritional health outcomes, including sleep behaviours. To our knowledge, the present work is the first to investigate associations between FI and the quality and quantity of sleep. The most significant finding of our study was that FI was associated with an increased risk of poor sleep quality in adults. Also, FI was associated with an increased risk of short and long sleep duration. Together, our findings highlight the adverse influence of FI on sleep behaviours.

Our observations add a novel dimension to current evidence about the negative influence of FI on sleep health status in the general adult population and extend previous reports. Our results are consistent with those of a cross-sectional study on patients with type 2 diabetes, and Bermúdez-Millán et al.[46] demonstrated that household FI is a common and potent household stressor related to suboptimal sleep quality through psychological distress. Similarly, Liu et al. corroborated associations between FI, frequent mental distress and insufficient sleep among adults across twelve states in the USA.[39] Consistently, Pinto et al.[47] reported that FI is associated with increased

Table 2 Subgroup analysis to assess the associations between food insecurity and the quality and quantity of sleep

Subgroup	Number of studies	OR*	95 % CI	P-value	I^2 (%)	P-value for heterogeneity†	P-value for between subgroup comparisons‡
Poor sleep quality risk							
Food insecurity degree							
Mild	5	1·31	1·16, 1·48	<0·001	0·0	0·41	0·003
Moderate	5	1·49	1·32, 1·68	<0·001	0·0	0·50	
Severe	5	1·89	1·63, 2·20	<0·001	0·0	0·82	
Sleep problems							
Trouble falling asleep	3	1·39	1·05, 1·83	0·02	91·4	<0·001	0·258
Trouble staying asleep	3	1·91	1·37, 2·67	0·001	89·3	<0·001	
Country							
USA	6	1·44	1·22, 1·70	<0·001	95·1	<0·001	0·817
Mexico	1	1·55	1·36, 1·77	<0·001			
Age							0·525
< 50	6	1·41	1·20, 1·66	<0·001	95·2	<0·001	
≥50	1	1·71	1·42, 2·06	<0·001	–	–	
Race							
Mixed	6	1·44	1·22, 1·70		95·1	<0·001	0·817
Latina	1	1·55	1·36, 1·77		–	–	
Number of participants							
<4000	3	1·57	1·06, 2·31	0·02	95·5	0·023	0·738
>4000	4	1·42	1·16, 1·75	<0·001	95	0·001	
Adjustments							
BMI							
Yes	4	1·50	1·14, 1·97	0·003	96·8	<0·001	0·788
No	3	1·40	1·08, 1·81	0·011	90·5	<0·001	
Sex							
Yes	5	1·41	1·17, 1·70	<0·001	95·3	<0·001	0·697
No	2	1·54	1·29, 1·82	<0·001	62·7	0·101	
Mental health							
Yes	2	1·54	1·29, 1·82	<0·001	62·7	0·101	0·697
No	5	1·41	1·17, 1·70	<0·001	95·3	<0·001	
Education status							
Yes	4	1·60	1·17, 2·18	0·003	94·2	<0·001	0·448
No	3	1·35	1·09, 1·67	0·007	95·3	<0·001	
Income status							
Yes	3	1·48	1·06, 2·06	0·021	95·7	<0·001	0·955
No	4	1·44	1·16, 1·79	0·001	94·1	<0·001	
Short sleep duration risk							
Food insecurity degree							
Mild	2	1·03	0·86, 1·22	0·76	0·0	0·74	0·085
Moderate	2	1·01	0·84, 1·22	0·89	0·0	0·53	
Severe	2	1·59	1·16, 2·18	0·004	45·9	0·17	
Age							
< 50	2	1·21	1·08, 1·36	0·001	0·0	0·41	0·316
≥50	2	1·11	1·02, 1·19	0·01	0·0	0·85	
Race							
Mixed	3	1·14	1·05, 1·23	0·002	12·9	0·31	0·732
Latina	1	1·17	1·02, 1·35	0·028	–	–	
Number of participants							
<4000	2	1·17	1·02, 1·34	0·02	52·0	0·14	0·874
>4000	2	1·14	1·02, 1·27	0·02	0·0	0·53	
Long sleep duration risk							
Food insecurity degree							
Mild	2	1·02	0·83, 1·25	0·83	0·0	0·64	0·274
Moderate	2	1·05	0·82, 1·33	0·70	0·0	0·59	
Severe	2	1·31	0·98, 1·76	0·06	0·0	0·92	
Age							
< 50	2	1·13	0·99, 1·29	0·07	0·0	0·57	0·869
≥50	2	1·15	0·99, 1·34	0·07	2·6	0·31	
Race							
Mixed	3	1·16	1·02, 1·33	0·02	0·0	0·56	0·689
Latina	1	1·11	0·96, 1·29	0·16	–	–	
Number of participants							
<4000	2	1·20	1·04, 1·38	0·01	0·0	0·85	0·446
>4000	2	1·09	0·95, 1·25	0·22	0·0	0·49	

*Calculated by random-effects model.
†P-value for heterogeneity within the subgroup.
‡P-value for heterogeneity between subgroups using meta-regression analyses.
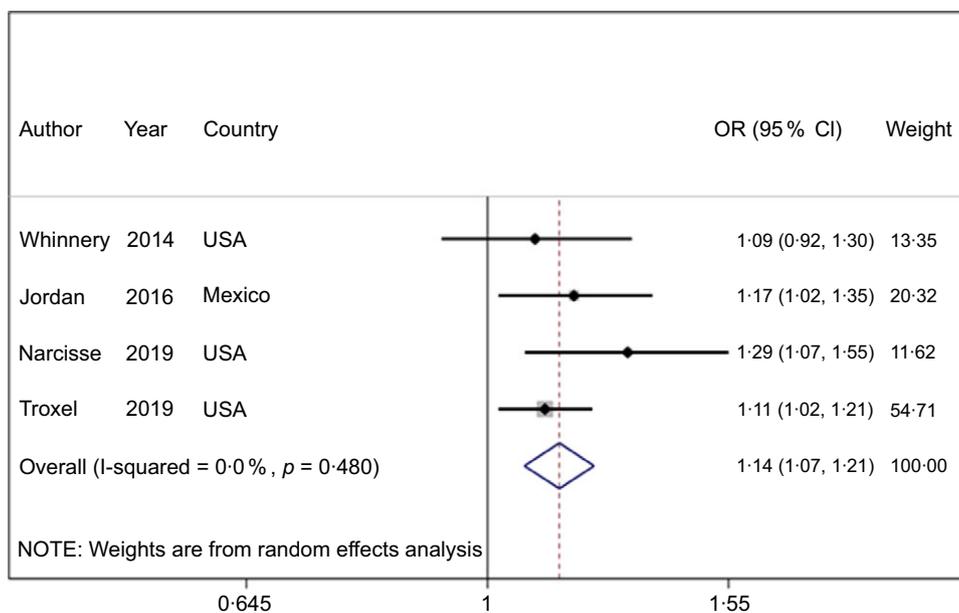
Table 3 Findings from meta-regressions

Poor sleep quality risk	Effect size, number of studies	OR	95 % CI	I^2 residual	P-value
Food insecurity degree	15	1·19	1·07, 1·32	0·0	0·003
Sleep problems	6	1·37	0·70, 2·69	90·47	0·258
Country	7	1·06	0·53, 2·14	95·1	0·817
Age	7	1·20	0·60, 2·39	95·22	0·525
Race	7	1·06	0·53,2·14	95·1	0·817
Number of participants	7	0·93	0·56, 1·55	95·24	0·738
Adjustments					
BMI	7	0·94	0·56, 1·57	95·66	0·788
Sex	7	1·09	0·63, 1·86	94·28	0·697
Mental health	7	0·91	0·53, 1·57	94·28	0·697
Education status	7	0·86	0·53, 1·37	94·66	0·448
Income status	7	0·98	0·59, 1·63	94·85	0·955
Short sleep duration risk					
Food insecurity degree	6	1·23	0·95, 1·59	37·82	0·085
Age	4	0·91	0·67, 1·22	0·0	0·316
Race	4	1·03	0·71, 1·49	12·89	0·732
Number of participants	4	0·98	0·69, 1·39	19·13	0·874
Long sleep duration risk					
Food insecurity degree	6	1·11	0·87, 1·43	0·0	0·274
Age	4	1·01	0·65, 1·57	0·0	0·869
Race	4	0·95	0·61, 1·47	0·0	0·689
Number of participants	4	0·90	0·58, 1·40	0·0	0·446

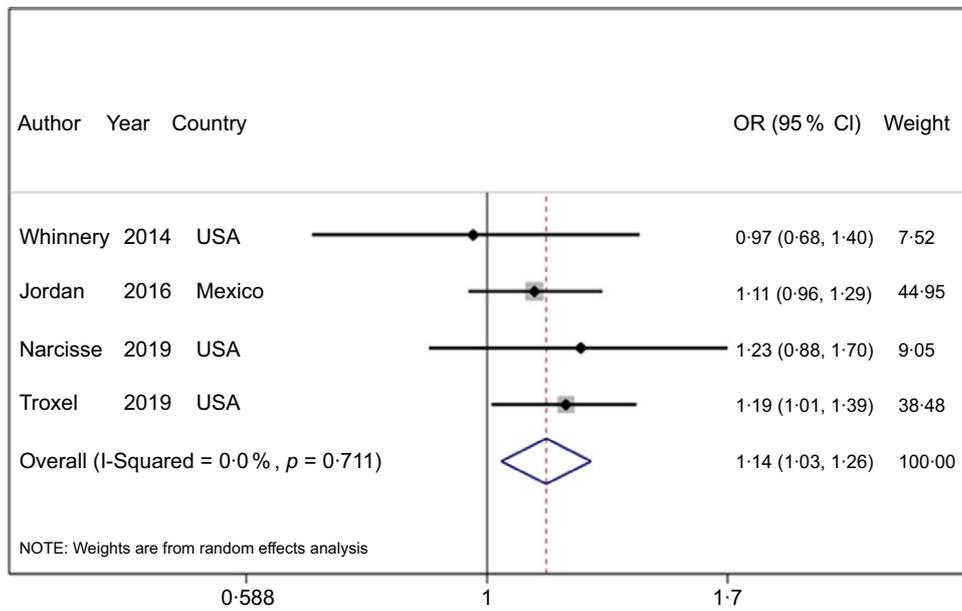odds (OR: 2·25; 95 % CI (1·11, 4·55)) of poor sleep quality in children.

The biological and psychosocial factors involved in mechanisms behind the association between FI status and adult sleep behaviours are less clear. However, this relationship may be mediated, at least partially, through mental health disorders (e.g. depression or depressive symptoms)[48]. FI is associated with an increased risk of depression[49–51], anxiety[52] or stress[53,54]. These mental health complications are known to be associated with adverse sleep quality[55,56]. Individuals affected by FI present with perceived powerlessness, disappointment, embarrassment and guilt, which may contribute to anxiety and depressive symptoms[57]. Furthermore, those with FI are more likely to consume convenience foods that are usually high in fat and refined sugars and are subsequently linked with poorer mental health through mechanisms explained in greater detail previously[8,58,59]. Stress and depression may also exacerbate FI status secondary hormonal imbalance, including aggravated cortisol secretion and dysregulation of the hypothalamic–pituitary–adrenal axis[9]. These alterations have been known to disrupt sleep[60,61]. Sleep disturbances can, in turn, alter appetite regulation medicated by increasing ghrelin and decreasing leptin levels. The compensatory mechanism of leptin reduces appetite and increases energy expenditure through the hypothalamic receptors[62]. Also, low leptin levels have been associated with poor sleep quality and a propensity for depressive symptoms[62]. Presently, the relative contributions of these individual factors to sleep behaviours are less conclusive by robust evidence, pointing to a research gap
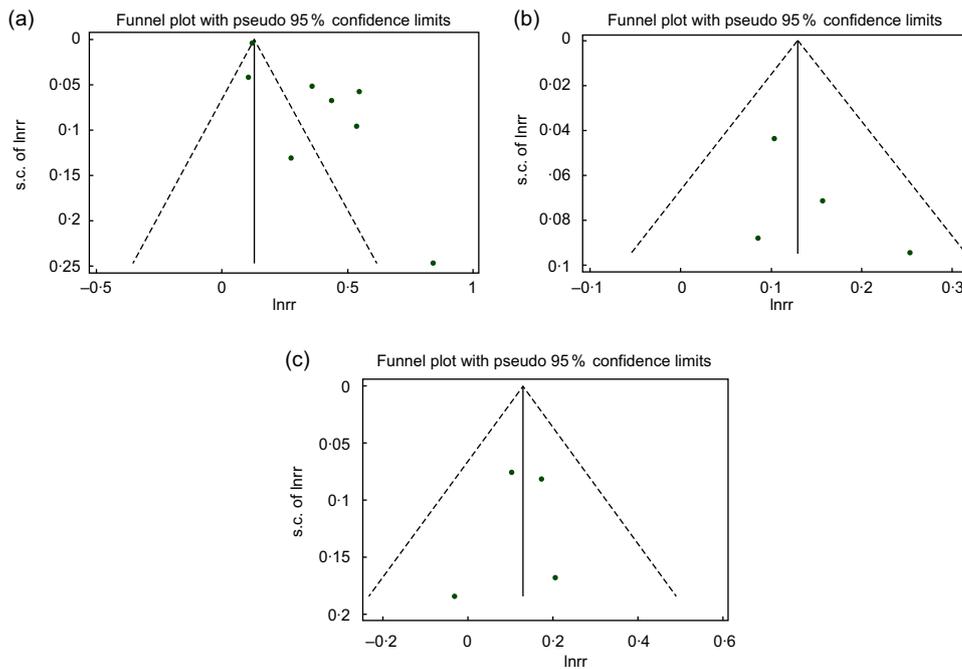
This study has some strengths, including a comprehensive search strategy. This is the first meta-analysis to report associations between FI and sleep quality and quantity. Most studies included in our meta-analysis accounted for critical confounding factors. We performed several subgroup analyses to determine the source of the heterogeneity. However, important limitations should be

Author	Year	Country	OR (95 % CI)	Weight
Whinnery	2014	USA	1·09 (0·92, 1·30)	13·35
Jordan	2016	Mexico	1·17 (1·02, 1·35)	20·32
Narcisse	2019	USA	1·29 (1·07, 1·55)	11·62
Troxel	2019	USA	1·11 (1·02, 1·21)	54·71
Overall (I-squared = 0·0 % , p = 0·480)			1·14 (1·07, 1·21)	100·00

NOTE: Weights are from random effects analysis

Fig. 3 Forest plot showing the OR with 95 % CI of the association between food insecurity and the risk of short sleep duration

Fig. 4 Forest plot showing OR with 95 % CI of the association between food insecurity and the risk of long sleep duration

Fig. 5 Funnel plot for evaluation publication bias in studies reporting OR and 95 % CI of the association between food insecurity and risk of poor sleep quality (a), short sleep duration (b), and long sleep duration (c)

acknowledged in the interpretation of our findings. Our work included cross-sectional studies. Therefore, no causality may be inferred on the link between FI and sleep behaviours. Most included studies relied on self-reported measures for FI and sleep. Accordingly, our observations are likely prone to over- or under-estimations of these measures secondary to the recall bias. Most (eight) studies were conducted in the USA; therefore, our findings may not be generalisable to low- and middle-income countries.

Moreover, we observed considerable variability across studies in methods (e.g. surveys) used to measure FI and sleep outcomes, possibly contributing to measurement errors and a misclassification bias, which have been corroborated in systematic reviews and meta-analyses of this type[63,64]. Also, the assessment of FI and sleep behaviours occurred in different years, making it challenging to detect whether FI levels remained unchanged when sleep behaviours were evaluated. We observed significant

heterogeneity among included studies for sleep quality. The heterogeneity was attenuated when the meta-analysis was subgrouped by the level of FI, and these results were approved following meta-regression analyses. However, other factors include sleep problems, country, age, race, number of participants and study adjustments did not explain the sources of heterogeneity. Our observations highlight the need for further research to elucidate the underlying factors and mechanisms that could explain the link between FI and poor sleep behaviours.

Conclusions

The present meta-analysis of observational studies revealed that FI was associated with poor sleep quality and quantity in adults. Our observations extend the growing evidence on associations between FI and physical and mental health. Findings from the present work highlight the need for preventative and management strategies that address FI and sleep behaviours. Future well-designed longitudinal studies with larger sample sizes should confirm our observations.

Acknowledgements

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980022002488

References

1. Anderson SA (1990) Core indicators of nutritional state for difficult-to-sample populations. *J Nutr* **120**, 1555–1600.
2. Lee JS (2013) Food insecurity and healthcare costs: research strategies using local, state, and national data sources for older adults. *Adv Nutr* **4**, 42–50.
3. Nations FAOU, Development IFA, Programme WF *et al.* (2020) *The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Healthy Diets*. Rome, Italy: Food and Agriculture Organization.
4. Tait CA, L'Abbe MR, Smith PM *et al.* (2018) The association between food insecurity and incident type 2 diabetes in Canada: a population-based cohort study. *PLoS ONE* **13**, e0195962.
5. Liu Y & Eicher-Miller HA (2021) Food insecurity and cardio-vascular disease risk. *Curr Atheroscler Rep* **23**, 24.
6. Moradi S, Arghavani H, Issah A *et al.* (2018) Food insecurity and anaemia risk: a systematic review and meta-analysis. *Public Health Nutr* **21**, 3067–3079.
7. Park SH & Strauss SM (2020) Food insecurity as a predictor of metabolic syndrome in US female adults. *Public Health Nurs* **37**, 663–670.
8. Moradi S, Mirzababaei A, Dadfarma A *et al.* (2019) Food insecurity and adult weight abnormality risk: a systematic review and meta-analysis. *Eur J Nutr* **58**, 45–61.
9. Pourmotabbed A, Moradi S, Babaei A *et al.* (2020) Food insecurity and mental health: a systematic review and meta-analysis. *Public Health Nutr* **23**, 1778–1790.
10. Sun Y, Liu B, Rong S *et al.* (2020) Food insecurity is associated with cardiovascular and all-cause mortality among adults in the United States. *J Am Heart Assoc* **9**, e014629.
11. Pourmotabbed A, Boozari B, Babaei A *et al.* (2020) Sleep and frailty risk: a systematic review and meta-analysis. *Sleep Breath* **24**, 1187–1197.
12. Pourmotabbed A, Ghaedi E, Babaei A *et al.* (2019) Sleep duration and sarcopenia risk: a systematic review and dose-response meta-analysis. *Sleep Breath* **24**, 1–12.
13. Madrid-Valero JJ, Martinez-Silva JM, Couto BRD *et al.* (2017) Age and gender effects on the prevalence of poor sleep quality in the adult population. *Gac Sanit* **31**, 18–22.
14. Visvalingam N, Sathish T, Soljak M *et al.* (2020) Prevalence of and factors associated with poor sleep quality and short sleep in a working population in Singapore. *Sleep Health* **6**, 277–287.
15. Sa J, Choe S, Cho B-Y *et al.* (2020) Relationship between sleep and obesity among U.S. and South Korean college students. *BMC Public Health* **20**, 96.
16. Deng X, Liu X & Fang R (2020) Evaluation of the correlation between job stress and sleep quality in community nurses. *Medicine* **99**, e18822.
17. Xiong J, Lan L, Lian Z *et al.* (2020) Associations of bedroom temperature and ventilation with sleep quality. *Sci Technol Built Environ* **26**, 1274–1284.
18. Kieliszek M & Lipinski B (2020) Selenium supplementation in the prevention of coronavirus infections (COVID-19). *Med Hypotheses* **143**, 109878.
19. Snel J & Lorist MM (2011) Effects of caffeine on sleep and cognition. *Prog Brain Res* **190**, 105–117.
20. Inkelis SM, Hasler BP & Baker FC (2020) Sleep and alcohol use in women. *Alcohol Res* **40**, 13.
21. St-Onge MP, Mikic A & Pietrolungo CE (2016) Effects of diet on sleep quality. *Adv Nutr* **7**, 938–949.
22. Ding M, Keiley MK, Garza KB *et al.* (2015) Food insecurity is associated with poor sleep outcomes among US adults. *J Nutr* **145**, 615–621.
23. Hagedorn RL, Olfert MD, MacNell L *et al.* (2021) College student sleep quality and mental and physical health are associated with food insecurity in a multi-campus study. *Public Health Nutr* **24**, 4305–4312.
24. Isaura ER, Chen Y-C, Su H-Y *et al.* (2020) The relationship between food security status and sleep disturbance among adults: a cross-sectional study in an Indonesian population. *Nutrients* **12**, 3411.
25. Jordan ML, Perez-Escamilla R, Desai MM *et al.* (2016) Household food insecurity and sleep patterns among Mexican adults: results from ENSANUT-2012. *J Immigr Minor Health* **18**, 1093–1103.

26. Nagata JM, Palar K, Gooding HC *et al.* (2019) Food insecurity is associated with poorer mental health and sleep outcomes in young adults. *J Adolesc Health* **65**, 805–811.

27. El Zein A, Shelnutt KP, Colby S *et al.* (2019) Prevalence and correlates of food insecurity among U.S. college students: a multi-institutional study. *BMC Public Health* **19**, 660.

28. Grandner MA, Chakravorty S, Perlis ML *et al.* (2014) Habitual sleep duration associated with self-reported and objectively determined cardiometabolic risk factors. *Sleep Med* **15**, 42–50.

29. Troxel WM, Haas A, Ghosh-Dastidar B *et al.* (2020) Food insecurity is associated with objectively measured sleep problems. *Behav Sleep Med* **18**, 719–729.

30. Narcisse MR, Long CR, Felix H *et al.* (2018) The mediating role of sleep quality and quantity in the link between food insecurity and obesity across race and ethnicity. *Obesity* **26**, 1509–1518.

31. Whinnery J, Jackson N, Rattanaumpawan P *et al.* (2014) Short and long sleep duration associated with race/ethnicity, sociodemographics, and socioeconomic position. *Sleep* **37**, 601–611.

32. Page MJ, McKenzie JE, Bossuyt PM *et al.* (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* **372**, n71.

33. Modesti PA, Reboldi G, Cappuccio FP *et al.* (2016) Panethnic differences in blood pressure in Europe: a systematic review and meta-analysis. *PLoS ONE* **11**, e0147601.

34. DerSimonian R & Laird N (1986) Meta-analysis in clinical trials. *Control Clin Trials* **7**, 177–188.

35. Coates J, Swindale A & Bilinsky P (2007) *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide*. Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

36. Baker WL, White CM, Cappelleri JC *et al.* (2009) Understanding heterogeneity in meta-analysis: the role of meta-regression. *Int J Clin Pract* **63**, 1426–1434.

37. Bermúdez-Millán A, Perez-Escamilla R, Segura-Perez S *et al.* (2016) Psychological distress mediates the association between food insecurity and suboptimal sleep quality in Latinos with type 2 diabetes mellitus. *J Nutr* **146**, 2051–2057.

38. Duh-Leong C, Messito M-J, Katzow MW *et al.* (2020) Material hardships and infant and toddler sleep duration in low-income Hispanic families. *Acad Pediatr* **20**, 1184–1191.

39. Liu Y, Njai RS, Greenlund KJ *et al.* (2014) Relationships between housing and food insecurity, frequent mental distress, and insufficient sleep among adults in 12 US States, 2009. *Prev Chronic Dis* **11**, E37.

40. Na M, Eagleton SG, Jomaa L *et al.* (2020) Food insecurity is associated with suboptimal sleep quality, but not sleep duration, among low-income Head Start children of pre-school age. *Public Health Nutr* **23**, 701–710.

41. Richards AL & Specker B (2021) Evaluating hours of sleep and perceived stress on dietary cognitive restraint in a survey of college students. *J Am Coll Health* **68**, 824–831.

42. Widome R, Jensen A, Bangerter A *et al.* (2015) Food insecurity among veterans of the US wars in Iraq and Afghanistan. *Public Health Nutr* **18**, 844–849.

43. Wang Q (2021) Food insecurity and sleep disturbance among 223,561 adolescents: a multi-country analysis of cross-sectional surveys. *Front Public Health* **9**, 693544.

44. Gyasi RM, Asamoah E, Gyasi-Boadu N *et al.* (2022) Food insecurity and sleep quality among older adults: findings from a population-based study in Ghana. *Maturitas* **157**, 27–33.

45. Cheng ER, Luo M, Perkins M *et al.* (2022) Household food insecurity is associated with obesogenic health behaviors among a low-income cohort of pregnant women in Boston, MA. *Public Health Nutr*, 1–9.

46. Bermúdez-Millán A, Perez-Escamilla R, Segura-Perez S *et al.* (2016) Psychological distress mediates the association

47. Pinto LC & Bertoluci MC (2020) Type 2 diabetes as a major risk factor for COVID-19 severity: a meta-analysis. *Arch Endocrinol Metab* **64**, 199–200.

48. Silverman J, Kriegar J, Kiefer M *et al.* (2015) The relationship between food insecurity and depression, diabetes distress and medication adherence among low-income patients with poorly-controlled diabetes. *J Gen Intern Med* **30**, 1476–1480.

49. Heflin CM, Siefert K & Williams DR (2005) Food insufficiency and women's mental health: findings from a 3-year panel of welfare recipients. *Soc Sci Med* **61**, 1971–1982.

50. Tsai AC, Bangsberg DR, Frongillo EA *et al.* (2012) Food insecurity, depression and the modifying role of social support among people living with HIV/AIDS in rural Uganda. *Soc Sci Med* **74**, 2012–2019.

51. German L, Kahana C, Rosenfeld V *et al.* (2011) Depressive symptoms are associated with food insufficiency and nutritional deficiencies in poor community-dwelling elderly people. *J Nutr Health Aging* **15**, 3–8.

52. Hadley C & Patil CL (2006) Food insecurity in rural Tanzania is associated with maternal anxiety and depression. *Am J Hum Biol* **18**, 359–368.

53. Hamelin A-M, Habicht J-P & Beaudry M (1999) Food insecurity: consequences for the household and broader social implications. *J Nutr* **129**, 525S–528S.

54. Seligman HK, Laraia BA & Kushel MB (2010) Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr* **140**, 304–310.

55. Zou P, Wang X, Sun L *et al.* (2020) Poorer sleep quality correlated with mental health problems in college students: a longitudinal observational study among 686 males. *J Psychosom Res* **136**, 110177.

56. João KADR, Jesus SND, Carmo C *et al.* (2018) The impact of sleep quality on the mental health of a non-clinical population. *Sleep Med* **46**, 69–73.

57. Whittle HJ, Palar K, Seligman HK *et al.* (2016) How food insecurity contributes to poor HIV health outcomes: qualitative evidence from the San Francisco Bay Area. *Soc Sci Med* **170**, 228–236.

58. Lang UE, Beglinger C, Schweinfurth N *et al.* (2015) Nutritional aspects of depression. *Cell Physiol Biochem* **37**, 1029–1043.

59. Lane MM, Davis JA, Beattie S *et al.* (2021) Ultraprocessed food and chronic noncommunicable diseases: a systematic review and meta-analysis of 43 observational studies. *Obes Rev* **22**, e13146.

60. Coplan JD, Gupta NK, Karim A *et al.* (2017) Maternal hypothalamic-pituitary-adrenal axis response to foraging uncertainty: a model of individual *vs.* social allostasis and the "superorganism hypothesis". *PLoS ONE* **12**, e0184340.

61. Vgontzas AN & Chrousos GP (2002) Sleep, the hypothalamic–pituitary–adrenal axis, and cytokines: multiple interactions and disturbances in sleep disorders. *Endocrinol Metab Clin* **31**, 15–36.

62. Frank S, Gonzalez K, Lee-Ang L *et al.* (2017) Diet and sleep physiology: public health and clinical implications. *Front Neurol* **8**, 393.

63. Kazemi M, Hadi A, Pierson RA *et al.* (2021) Effects of dietary glycemic index and glycemic load on cardiometabolic and reproductive profiles in women with polycystic ovary syndrome: a systematic review and meta-analysis of randomized controlled trials. *Adv Nutr* **12**, 161–178.

64. Kazemi M, Kim JY, Wan C *et al.* (2022) Comparison of dietary and physical activity behaviors in women with and without polycystic ovary syndrome: a systematic review and meta-analysis of 39471 women. *Hum Reprod Update* **28**, 910–955.