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Examining the Physical Environment and Social Determinants on Sleep

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A thesis submitted in partial fulfilment of the requirements for the award of Doctor of Clinical Psychology at the University of Sheffield

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Declaration

I, the author, declare that this thesis is my own work, and it is submitted for the award of Doctorate in Clinical Psychology at the University of Sheffield. This work has not been submitted to any other institutions or other degrees and qualifications. There are no conflicts of interests, and no funding has been received for this work.

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Lay summary

Poor sleep affects people all over the world and it could impact both physical and mental health. Therefore, understanding the reasons that impacts sleep could highlight ways of how to improve it.

Literature review: The quality of the physical environment could impact health. But little was known about how the physical environment impacted sleep in the long-term. In three databases, 21 cohort and experimental papers were found that assessed this. Fourteen of these papers showed that more noise, air pollution, and negative neighbourhood surroundings, such as crime and disorder, had a negative impact on sleep. Meanwhile, more green spaces, better neighbourhood design and steps taken to reduce noise was linked to better sleep. But there was no link between walkability and sleep. Also, a small number of papers found no links to sleep or that more air pollution was linked to better sleep, probably because they used different approaches to gather information from participants. Still, this suggested that improving the physical environment might lead to better sleep.

Empirical study: Social determinants, meaning social, economic and environmental factors, could impact sleep because they could influence the conditions people live in and access to resources. To understand this better, this study looked at how poor sleep was linked with social determinants and mental health difficulties in 2513 people. This showed that having support and higher age was linked to better sleep. While difficulties with paying for necessities, being female, financially secure, and having a minority sexual orientation was linked to worse sleep, possibly because of stress. Poor sleep also impacted the connection between worse mental health and these factors too, but ethnicity and declared religion was not linked to sleep or mental health. This pointed out that making improvements in society might improve sleep and therefore also mental health.

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Section One: Literature Review

Longitudinal Association Between the Physical Environment on Sleep Health in Adults: A Systematic Review and Narrative Synthesis

Abstract

Objectives: Sleep health has been recognised as a determinant for mental and physical health, where the wider environmental context could influence sleep. This systematic review aimed to assess longitudinal associations between the physical environment on sleep health in adults.

Method: Three databases (Medline, PsycINFO and Scopus) were used to search for relevant papers. Inclusion criteria encompassed peer-reviewed studies with a longitudinal design assessing the physical environment on sleep health in adults. A narrative synthesis was used to analyse the data.

Results: Twenty-one papers were identified. K = 14 observed that increased noise (k = 3) and air pollution (k = 4), and adverse physical neighbourhood characteristics (crime and disorder; k = 2), was associated with negative sleep outcomes, whilst increased green spaces and vegetation (k = 3), interventions aimed to reduce noise (k = 4), and better urban design (k = 1) was linked to improved sleep health. However, there was no impact of walkability on sleep (k = 2). The quality assessment was high across studies, yet there was variability across the dimensions and methodological differences, which could have contributed to some variations between and within the studies, in terms of the direction of the relationships.

Conclusion: This provided insight into wider physical environmental factors contributing to sleep health, which remains a significant concern across all sectors of public health. Interventions and policies ought to reflect this on a public health level, where future research is urged to examine the impact from these changes.

Keywords: sleep, physical environment, noise, air, urban design, crime, neighbourhood disorder, green spaces, walkability, adults.

Practitioner Points

- Taking a public health approach in collaboration with wider stakeholders to address physical environmental factors contributing to sleep health.
- Collaborating on interventions to improve neighbourhood disorder, noise and air pollution, and green spaces.
- Advocating for policy changes reflecting the impact from physical environmental factors on sleep.

Introduction

Sleep health is characterised by adequate sleep duration, sleep efficiency, appropriate timing of sleep, alertness during hours awake, and sleep quality (Buysse, 2014), and it has been recognised as a determinant for mental and physical health (Czeisler, 2015). Indeed, poor sleep health has been found to increase prevalence of chronic conditions including stroke (Wang et al., 2022a), cardiovascular diseases, heart failure (Wang et al., 2022b), asthma (Liu et al., 2023a), and predict mental health (Zhang et al., 2024). In contrast, improving sleep has been associated with enhanced well-being, physical health (Tang et al, 2017) and mental health (Scott et al., 2021). Despite the importance of sleep on health, 25% of people globally have reported dissatisfied sleep (Morin & Benca, 2012).

Sleep encompasses a biological need, opportunity to sleep, and ability to initiate sleep (Tubbs et al., 2019). In turn, these factors could be altered by the physical environment (Kim, 2022a), which has been proposed to impact health directly through manipulating the environmental quality, or indirectly through behaviours (Pinter-Wollman et al., 2018). Indeed, the socioecological model of sleep health has highlighted the influence of individual factors embedded in contextual wider factors and broader transcending systemic systems in which people inhabit, including the physical environment (Grandner, 2019). Alongside this, the physical environment could trigger physiological stress systems (Liu et al., 2021), where the allostatic load framework posits that this continued exposure could lead to over-activation and therefore physiological dysregulation, in contrast to adaptive stress responses from short term exposure (McEwen & Stellar, 1993). Correspondingly, recurring exposure from environmental stressors might therefore gradually result in maladaptive change in sleep only detectable over time (Han et al., 2012). Subsequently, considering physical environmental determinants on sleep across phases could be important. In line with the upstream-downstream metaphor, this was aligned with an upstream approach by considering

underlying root causes that could identify prevention targets, rather than a downstream perspective by reactively managing the symptoms from those consequences (McMahon, 2022).

Emerging research has suggested that the physical environment could be an important upstream determinant on sleep health (Johnson et al., 2019) which encompasses; the natural environment involving green spaces or vegetation; the ambient environment such as sound and atmosphere (Billings et al., 2020; Johnson et al., 2019); and the neighbourhood environment, including urban design such as landscaping, public street art and signage, and walkability influenced by street connectivity and pavements, in addition to disorder, violence, and crime contributing to physical features of inadequate maintenance, poor condition of buildings, abandoned buildings, graffiti and litter (Billings et al., 2020; Marco et al., 2015; 2006; Zhao et al., 2025). The literature has documented several aspects of the physical environment as possible risk factors for sleep health including air pollution, ambient noise, neighbourhood disorder, including violence and crime, and absence of green spaces and walkability (Billings et al., 2020; Hale et al., 2020; Hunter & Hayden, 2018).

Noise pollution, defined as unwanted harmful sound exceeding 40 decibels at night (World Health Organization [WHO], 2010), has been found to be more prevalent in urban areas (Muzet, 2007). This has been proposed to activate the sympathetic stress response, triggering the hypothalamic-pituitary-adrenal (HPA) axis leading to release of cortisol and increased arousal that disrupt sleep (Liu et al., 2021). A systematic review and meta-analysis by Smith et al. (2022) found that transportation noise was negatively associated with self-reported sleep, and similar findings was reported in a narrative review by Hunter and Hayden (2018). Indeed, noise pollution from road, rail and air traffic have been shown to hinder sleep, where closer proximity has been linked to worsen sleep (Perron et al., 2016). This could be problematic as approximately 30% of the European Union population have been

exposed to nighttime road traffic noise levels surpassing the WHO's recommendations (WHO, 2010).

Similar to noise, air pollution has been linked to more harmful levels in concentrated urban areas (Billings et al., 2020). Correspondingly, about 99% of the world's population have been found to inhabit areas where air pollution levels have exceeded the recommendations by the WHO (WHO, 2024). Air pollution has been proposed to affect sleep through alteration of the biochemistry of the central nervous system, disrupting the regulation of sleep, in addition to changes in the respiratory system resulting in airflow obstruction or inflammation disrupting sleep (Liu et al., 2021). In line with this, a systematic review and meta-analysis by Zhao et al. (2023) observed that air pollution exposure was positively associated with sleep disorders. However, a review by Liu et al. (2020) and narrative review by Hunter and Hayden (2018) found mixed results, with air pollution generally being associated with poor sleep, yet some of the included studies reported that pollutants improved sleep.

In terms of physical characteristics of neighbourhoods, factors such as poor design, absence of walkability, and physical disorder, have been found to impact sleep health. These factors have been proposed to activate the sympathetic nervous system and associated stress-related responses, leading to reduced ability to relax and therefore poorer sleep (Mellman et al., 2018). Correspondingly, research has found that high levels of neighbourhood violence (Johnson, 2016), crime (Richardson, 2021) and disorder (DeSantis et al., 2013), in addition to negative attributes of urban design, such as unkempt landscaping (Sutil et al., 2024), were accompanied with worse sleep.

On a related note, walking conditions related to pavements, traffic, pleasant features, and recreational destinations could impact walkability (Smith et al., 2017) and in turn sleep.

A study by Adjaye-Gbewonyo et al. (2023) observed that access to walking paths and pavements was linked to better sleep, while unsafe walking conditions due to traffic and crime were associated with worse sleep. Similar findings were reported by Nam et al. (2018), where better walking conditions were associated with better sleep, yet another study by Troxel et al. (2018) found no effect of walkability on sleep. The walking environment could be an important component, as Gladwell et al. (2016) found that walking in a green environment improved sleep but not walking in a built environment. Correspondingly, access to green spaces and vegetation has been proposed to lower stress levels, promote relaxation and reduced exposure to noise and air pollutants (WHO, 2016), which has been linked to improved sleep (Grigsby-Toussaint et al., 2015). Indeed, a systematic review by Shin et al. (2020) found that green space exposure was linked with sleep improvements, which suggested that green spaces could act as a protective factor.

Overall, this suggested that the physical environment could influence sleep health. Previous systematic reviews (Hunter & Hayden, 2018; Kim et al., 2022a) and narrative reviews (Billings et al., 2020; Hale et al., 2020; Johnson et al., 2018; Liu et al., 2021) have assessed some elements of the physical environment on sleep, yet the majority of the included studies had a cross-sectional design. This significant limitation precluded causal conclusions, and the authors urged future research to examine the longitudinal or experimental impact of the environment on sleep to understand temporal and causal relationships (Billings et al., 2020; Hunter & Hayden, 2018; Johnson et al., 2018; Kim et al., 2022a). Additionally, as sleep could recover from short-term stress, yet persist under repeated exposure (Han et al., 2012), cross-sectional associations could fail to detect improvement or decline from sustained environmental stressors. In contrast, longitudinal or experimental approaches could highlight how these exposures shape sleep health over time.

Therefore, the aim of the present systematic review was to assess longitudinal,

including experimental, associations between the physical environment on sleep health in adults to contribute to an understanding of causal association and changes over time. The broad spectrum of physical environmental factors, varied sleep health parameters and sleep measures across studies could result in a great deal of diversity and different effect measures, which could make it difficult to compare findings across studies to carry out a meta-analysis (McKenzie & Brennan, 2019). Therefore, a narrative synthesis was selected, as this would allow to describe complex and broad research that require nuanced detailed description and interpretation (Greenhalgh et al., 2018). Subsequently, this could identify physical environmental factors that hinder or promote healthy sleep over time, which could inform upstream preventative interventions and policies.

Method

Registration

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Appendix A; Page et al., 2021) guidelines were used for this review. Before conducting the main literature search, preliminary scoping searches were carried out in Scopus, PsycINFO and Medline on 21/10/2024, to assess whether there were sufficient studies on the topic. A protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) on 16/11/2024 prior to conducting the review (CRD42024564821).

Eligibility Criteria

The Population, Exposure, Outcome (PEO) framework guided the inclusion and exclusion criteria (table 1; Law et al., 1996). The studies needed to include a longitudinal design examining the physical environment on sleep health with adults, with at least two data points for sleep. Additionally, they had to be written in English and published in peer-reviewed research journals. Buysse (2014) definition of sleep health was used, marked by;

adequate sleep duration, the total amount of sleep in 24-hours; sleep efficiency, the total time spent in bed asleep; appropriate timing of sleep within 24-hours; maintaining alertness during hours awake; and sleep quality.

Table 1

Inclusion and exclusion criteria.

PEO	Criteria	
	Inclusion	**Exclusion**
Population	Adults aged ≥18 years.	Infant, children and adolescent < 18 years of age.
Exposure	Longitudinal exposure of the physical environment, including factors related to (a) air, (b) noise, (c) infrastructure, (d) the built environment including public housing, sanitation, fitness centers, care and recreation facilities, houses, and green spaces, and (e) residence characteristics, including rural, urban, poverty areas and populations, and neighbourhood safety, security, crime, violence, deprivation and overcrowding.	Indoor environments or environments not associated with the physical environment.
Outcome	Sleep health data, with at least two measuring points. Published in peer-reviewed original research journals. Written in the English-language. Longitudinal design, qualitative or quantitative, with at least two measuring points for sleep data (e.g., two-wave longitudinal studies or daily diaries).	Sleep data only reported once. Reviews, editorial letters, protocols, book chapters, conference proceedings, and review position papers.

Search Strategy

Three databases, including Medline, PsycINFO and Scopus were systematically searched on 17/11/2024 with no limitation to the date of publication. A subject specialist

librarian was consulted in relation to the selection of databases, search methodology and terms. These included a combination of keywords related to sleep health, the physical environment, and a longitudinal design, which were combined using Boolean operators, AND/OR, and an asterisk symbol for truncation (table 2). The search terms for the physical environment were adapted from a previous systematic review by Lund et al. (2018) to ensure consistency and comprehensiveness in capturing relevant studies.

Table 2

Search syntaxes.

Construct	Search term
Sleep health	Sleep
Physical environment	"noise pollution" OR "air pollution" OR "infrastructure" OR "built environment" OR "public housing" OR "sanitation" OR "fitness centers" OR "ambulatory care facilities" OR "health services accessibility" OR "parks recreational" OR "housing condition" OR "greenspace" OR "green space" OR "physical environment" OR "enviro* setting" OR "urban setting" OR "rural setting" OR "residence characteristics" OR "poverty areas" OR "rural population" OR "urban population" OR "neighbo* safety" OR "neighbo* security" OR "neighbo* deprivation" OR "crime" OR "violence" OR "overcrowding"
Longitudinal	"longitudinal" OR "repeated measures" OR "follow-up" OR "prospective" OR "cohort stud*"

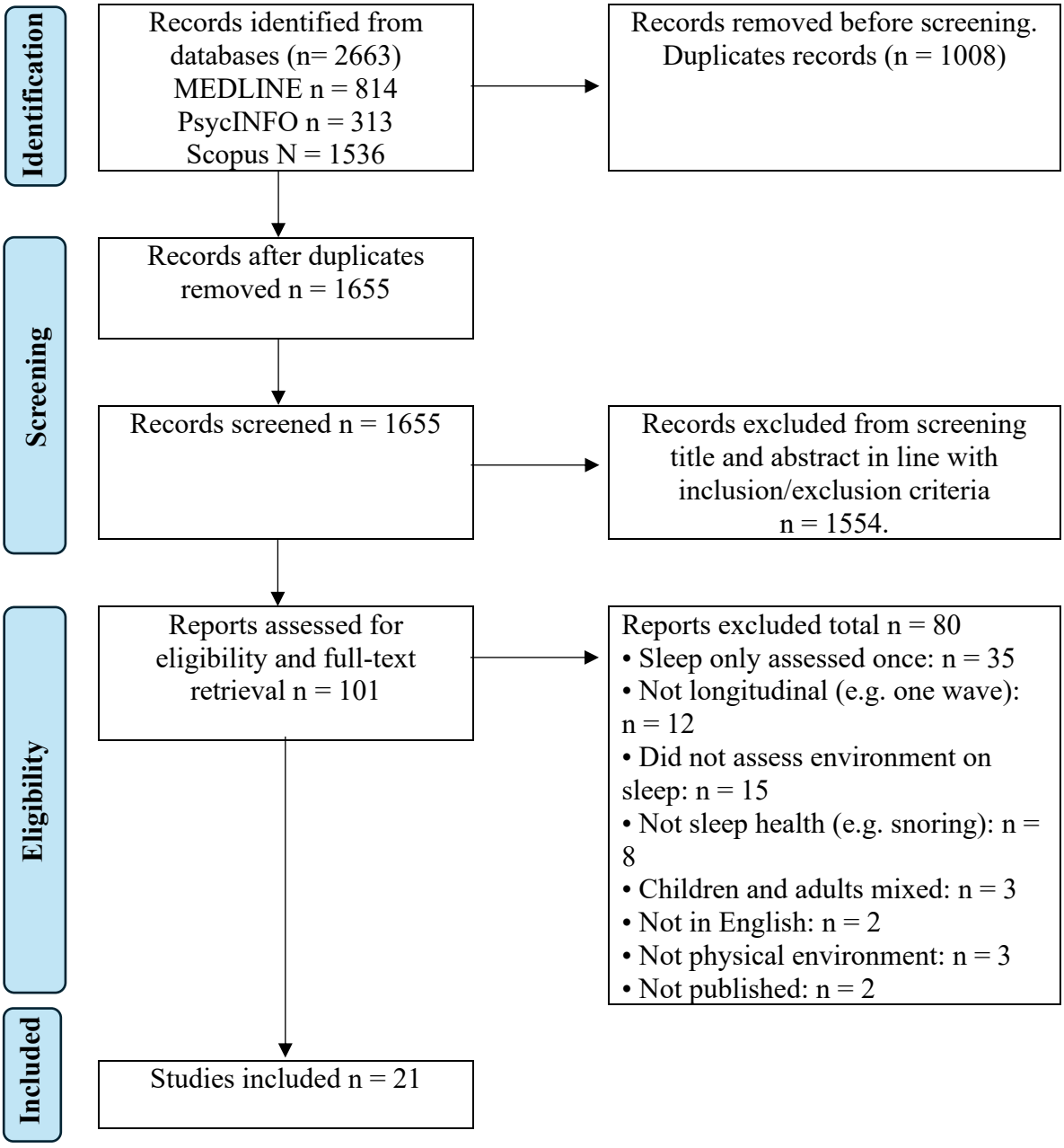
Note. Boolean operators were used, where "OR" was used to combine the search terms under each construct, followed by "AND" to combine the constructs.

The search terms were used to search for relevant papers through titles, abstracts and keywords. After the pool of potential studies had been identified, they were uploaded into Rayyan, a management tool for systematic reviews. Duplicates were identified and removed, followed by screening the title and abstract of each record for eligibility, and ineligible

studies were excluded based on the inclusion/exclusion criteria. Following this initial screening, the full-text versions of each article of interest were reviewed in detail and cross-referenced against the inclusion/exclusion criteria. The screening of the studies is outlined in a PRISMA flow diagram (figure 1; Moher et al., 2009).

Figure 2

PRISMA diagram



The screening was completed by the author and a sub-sample of records (k = 100) were checked by an independent reviewer (Clinical Psychologist) during the initial stage of the selection process. There was 98% agreement, and the remaining disagreements were resolved from discussion.

Data extraction

The data from each study were extracted by the author, which included, author(s), year of publication, country, design, follow-up period, population, physical environmental factor, sleep tool and main outcome related to the aim (table 3). The studies were organised under physical environmental category subheadings, where two studies were included twice under separate environmental factors. Authors were contacted to confirm significant change in sleep as occasionally the p-value was not provided in some papers. One author (Schreckenberg et al., 2016) also provided a figure with sleep change data. The present paper's author extracted this data to calculate the p-value ($p < .050$) using a paired t-test, yet with a disclaimer that the data extracted might have minor inaccuracies.

Synthesis

A narrative synthesis of the data was conducted, using Popay et al. (2006) guidance; a) developing a theory for the change; b) preliminary synthesis with textual descriptions, grouping clusters and thematic descriptions; c) assessing relationships between and within the studies with conceptual triangulation by evaluating the results and considering opposing findings; and d) examining robustness of the studies in terms of rigor to draw credible conclusions. A meta-analysis was not carried out due to the heterogeneity between the studies, marked by variation of physical environmental factors and measures of sleep (McKenzie & Brennan, 2019).

Quality Assessment

The critical appraisal skills programme (CASP) Cohort checklist (Critical Appraisal Skills Programme, 2022; Appendix B) and the Joanna Briggs Institute (JBI) Checklist for Quasi-Experimental Studies (Joanna Briggs Institute, 2020; Appendix C) were used to assess the quality and potential risk of bias for the cohort and quasi-experimental studies respectively. All studies were assessed by the author, and 20% of the studies were assessed by a second reviewer (Clinical Psychologist). Cohen's Kappa indicated substantial agreement k = 0.67.

The 12-criterions in the CASP tool have three responses ("yes" = 1; "no" = 0; "can't tell" = 0). A higher score indicated greater quality, where yes answers of ≤6 = low, 7-9 = moderate, and ≥10 = high rigour based on previous research (Smith et al., 2016). Additionally, the JBI tool had 9-criterions with four responses ("yes" = 1; "no" = 0; "unclear" = 0, "not applicable" = 0). Based on the attainable score for each study, the total "yes" responses were classified as <50% = low, 50%-69% = acceptable and ≥70% = good quality, in line with previous research (George et al., 2014). Thomas and Harden (2008) argued that solely including the most rigorous studies might exclude papers that could offer valuable insight. Therefore, all studies would be included, irrespective of their quality.

Results

Study Characteristics

The search provided 21 papers, encompassing k = 14 cohort and k = 7 quasi-experimental studies, published between 2004-2023 (table 3). All papers had a longitudinal design with a time range between 2 weeks to 9 years. Two papers (Liu et al., 2023b; Martens et al., 2018) appeared twice in the table and in the narrative synthesis as different physical environmental factors were considered within these papers. Additionally, k = 2 studies used

the same sample (Kim et al., 2022b; Kim et al., 2023), and these participants were considered twice.

The studies were conducted in different countries; k = 5 China (An & Yu, 2018; Liu et al., 2023b; Yu et al., 2017; Yu et al., 2019; Xu et al., 2023); k = 5 United States (Bozigar et al., 2023; Hu et al., 2024; Kim et al., 2022b; Kim et al., 2023; Li et al., 2020); k = 3 Sweden (Nilsson & Berglund, 2006; Stenfors et al., 2023; Öhrström, 2004); k = 2 Netherlands (Barros et al., 2024; Martens et al., 2018); k = 2 Switzerland (Brink et al., 2023; Héritier et al., 2014); k = 1 Australia (Astell-Burt & Feng, 2020); k = 1 Germany (Schreckenberg et al., 2016); k = 1 Norway (Amundsen et al., 2013); and k = 1 United Kingdom (Lin et al., 2023).

The sample size ranged from 75 to 40315 and different tools were used to assess sleep. K = 18 studies assessed self-reported sleep, where k = 9 studies used a survey (Astell-Burt & Feng, 2020; Barros et al., 2024; Bozigar et al., 2023; Brink et al., 2023; Héritier et al., 2014; Liu et al., 2023b; Schreckenberg et al., 2016; Öhrström, 2004), where one of these also used sleep logs (Öhrström, 2004). Moreover, K = 4 studies used items from questionnaires (k = 2 Fatigue in Medical Training Questionnaire, An & Yu, 2018 and Yu et al., 2017; k = 1 Basic Nordic Sleep Questionnaire, Amundsen et al., 2013; Chinese Pittsburgh Sleep Quality Index, Yu et al., 2019), k = 3 studies used questionnaires (k = 1 the Karolinska Sleep Questionnaire, Stenfors et al., 2023; k = 1 Medical Outcomes Study questionnaire, Martens et al., 2018) and k = 2 studies used bespoke unvalidated questionnaires (Lin et al., 2023; Nilsson & Berglund, 2006). Additionally, k = 5 studies assessed sleep objectively, where k = 1 study used a Fitbit device (Hu et al., 2024) and k = 4 studies used actigraphy (Kim et al., 2022b; Kim et al., 2023; Li et al., 2020; Xu et al., 2023), where two of these studies also used either a questionnaire (Groningen Sleep Quality, Xu et al., 2023) or a sleep diary (Li et al., 2020).

Table 3

Data Characteristics.

Author Country	Design	Population	Physical environment	Sleep tool	Main outcome
Noise pollution					
Amundsen et al. (2013) Norway	Quasi-experimental longitudinal design. Follow-up: 6-months and 2.5-years.	N = 436 residents (aged ≥18). N = 155 façade insulation intervention; n = 216 control-1; and n = 65 control-2 no pre.	Traffic noise (dB).	Survey (two items from the Basic Nordic Sleep Questionnaire.	99.73% and 62.48% completed each follow-up. Sleep disturbance was reduced between pre and post $p < .0005$ in the intervention group. Control groups: no sig.
Barros et al. (2024) Netherlands	Quasi-experimental longitudinal design. Follow-up: area 1 12-months, area 2 8-months, and area 3 11-months.	N = 373 residents (aged ≥18, M = 55.4 SD = 16.8; 53.9% female).	Traffic noise (dB) before and after installing or replacing noise barriers.	Survey.	98.32% completed follow-up. Lying awake in the morning increased in area 1 ($p < .050$) and area 3 ($p < .050$). No sig. in area 2 or control. Sleep duration reduced in area 1 ($p < .050$) and area 2 ($p < .050$). No sig. for area 3 or control. No sig. for time to fall asleep, oversleep in the morning and feeling rested in the morning.

Bozigar et al. (2023) United States	Cohort longitudinal design. Follow-up at: 2, 8, 12, and 14 years.	N = 35381(aged ≥18, M = 66.1, SD = 7.2; female 100%; white 96.1%) nurses from the Nationwide U.S. Nurses' Health Study.	Airport noise in dB.	Survey.	88.2%, 69%, 45% and 45.2% completed follow-ups at each wave. Higher nighttime noise was associated with greater likelihood of short sleep duration (OR = 1.23; CI: 1.07, 1.40).
Brink et al. (2023) Switzerland	Quasi-experimental longitudinal design. Follow-up: 1-2 years.	N = 1311 residents (aged ≥18).	Traffic noise in dB before and after a road speed reduction.	Survey.	67.05% completed follow-up. Sleep disturbance reduced between the timepoints ($t = 6.36$, $p < .010$). Reduced speed limit was associated with reduced sleep disturbance ($\beta = -0.56$, $p < .010$).
Héritier et al. (2014) Switzerland	Cohort longitudinal design. Follow-up: 1 year.	N = 1375 (age >30; female 59.1%) from the Health Related Quality of Life and Radio Frequency Electromagnetic Field Exposure study.	Traffic noise in dB and traffic noise annoyance in a survey.	Survey.	81.6% completed follow-up. Increased noise annoyance was associated with increased sleep disturbance: model 1 baseline $\beta = 0.10$ $p < .001$ and follow-up $\beta = 0.12$ $p < .001$; model 2 baseline $\beta = 0.11$, $p < .001$ and follow-up $\beta = 0.12$, $p < .001$). Indirect effects of increased road traffic; model 1 and 2: baseline $\beta = 0.04$, $p < .001$ and follow-up $\beta = 0.04$, $p < .001$).

Martens et al. (2018) Netherlands	Cohort longitudinal design. Follow-up: 4–5 years.	N = 14829 (31–65 years old; female 55.76%) from the Occupational and Environmental Health Cohort study.	Traffic noise in dB and self-reported exposure.	Medical Outcomes Study questionnaire.	53.3% completed follow-up. Cohort data: Increased in exposed noise (β = 0.05, p = .008) and self-reported noise (β = 0.83, p < .001) was associated with increase in sleep disturbance. Individual changes: Increased self-reported perceived noise was associated with increased sleep disturbance (β = 0.21, p = .019).
Nilsson & Berglund (2006) Sweden	Quasi-experimental longitudinal design. Follow-up: 2 years.	N = 736 residents (aged ≥18). N = 495 noise-barrier intervention and n = 241 control.	Traffic noise in dB and self-reported noise annoyance before and after a noise-barrier.	Questionnaire.	74% completed follow-up. Difficulties with falling asleep, awaken too early, and sleep quality were non sig.
Schreckenberg et al. (2016) Germany	Quasi-experimental longitudinal design. Follow-ups at: 1 and 2 years.	N = 9244 residents (aged ≥18; female 54%).	Aircraft noise in dB and survey before and after night flight ban (11pm-5am).	Survey.	52.65% and 37.9% completed all follow-ups. Sleep disturbance was reduced between pre and post for those experiencing a reduction in noise at 2dB (p < .001). Disturbance when falling asleep and early morning was not sig.
Öhrström (2004)	Quasi-experimental	N = 142 residents (aged ≥18; 54.3%	Traffic noise in dB and traffic load before and	Survey and a three-day sleep log.	84.5% completed follow-up.

Sweden	longitudinal design. Follow-up: 2 years.	female). N = 50 intervention group and n = 92 control.	after opening of a tunnel.		Survey pre and post: Alert in the morning (p = .002) increased and < 30 min to fall asleep (p = .001) reduced in the intervention group and difficulties falling asleep, awakenings, sleep quality and tiredness in the morning was non sig. Sleep log at pre and post: Woken by traffic noise (p = .002) and difficulty falling back to sleep (p = .005) reduced, and sleep quality (p = .005) increased in the intervention group. Difficulties falling asleep, < 30 min to fall asleep, awakenings and being tired were non sig. Control group no sig.
Xu et al. (2023) China	Quasi-experimental longitudinal design. Follow-up: 2 weeks.	N = 75 urban residents (aged ≥ 18; 37.3% female).	Noise in dB (condition 1 door and windows open in bedroom; condition 2 door and windows closed in bedroom).	Actigraphy and Groningen Sleep Quality Scale in survey.	84.5% completed follow-up. Total sleep time, WASO, sleep efficiency, and subjective sleep quality was non sig.

Adjustments:
Bozigar et al. (2023): age, race, United States region of residence, living alone, smoking status, alcohol consumption, hypertension, diabetes, greenness, spouse's education, and night light.
Brink et al. (2023): age, gender, and nighttime sound level (dB) at the bedroom façade.
Héritier et al. (2014): age, gender, marital status, education, physical activity, and smoking.
Martens et al. (2018): age, gender, smoking, education, neighbourhood income level, and year the measure was completed (baseline/follow-up).

Air pollution					
An & Yu (2018) China	Cohort longitudinal design. Follow-ups at: 6-9, 22, and 30-32 weeks.	N = 14110 (aged ≥18 M = 18.06 CI: 18.04, 18.07; 67.39% female) undergraduate students.	Air pollution PM2.5.	Survey (2-items from Fatigue in Medical Training Questionnaire).	87.1% completed follow-ups. Increased PM2.5 was associated with increased daily average hours of nighttime/daytime sleep β = 1.07, $p < .001$.
Li et al. (2020) United States	Prospective cohort longitudinal design. Follow-up: 6 weeks.	N =101 (aged ≥ 18 M = 35 SD = 12; female n = 86) with episodic migraines.	Air pollution PM2.5, SO2, NO2, O3 and CO.	Actigraphy and sleep diary.	97.03% completed follow-up. Increased O3 was sig. associated with increased sleep duration (β = 7.51; CI: 3.23, 11.79) with actigraphy. No other consistent association for O3, NO2, CO and SO2 with sleep duration, sleep latency, WASO and sleep efficiency.
Lin et al. (2023) United Kingdom	Prospective cohort longitudinal design. Follow-up: 8.7 years.	N = 40315 (aged 40–69; 48% female) from the UK Biobank.	Air pollution PM2.5, PM10, NOX, NO2, CO, and SO2.	Questionnaire.	100% n = 40315 selected for analysis. Increased CO (AHR = 1.83, $p < 0.001$), SO2 (AHR = 2.58; $p < 0.001$), PM10 (AHR = 1.35; $p < 0.001$) PM2.5 (AHR = 1.27; $p < 0.001$), NO2 (AHR = 1.10; $p < 0.001$), NOX (AHR = 1.06; $p < 0.001$) and all air pollution combined (AHR = 1.20, $p <$ .001) were associated with increased risk of insomnia.

Liu et al. (2023b) China	Prospective cohort longitudinal design. Follow-ups at: 2, 4, 6, and 8 years.	N = 21878 (aged ≥ 45, M = 59.0, SD = 11.0; 52.5% female) from the China Health and Retirement Longitudinal Study.	Air pollutants PM10, PM2.5, PM1 and NO2.	Survey.	Increased PM2.5 (OR = 1.07; CI: 1.04, 1.11) and PM10 (OR = 1.02; 1.01, 1.04) was sig. associated with increased likelihood of sleep disorders, and increased PM2.5 (β = -0.07; CI: 0.08, 0.05), PM10 (β = -0.04; CI: 0.05, 0.03) were also sig. associated with reduced sleep duration. NO3 (β = 0.05; 0.02, 0.09) was sig. associated with increased sleep duration. No other consistent association.
Martens et al. (2018) Netherlands	Cohort longitudinal design. Follow-up: 4–5 years.	N = 14829 (31–65 years old; female 55.76%) from the Occupational and Environmental Health Cohort study.	Air pollution NO2, NOX, PM2.5 and PM10, and self-reported exposure.	Medical Outcomes Study questionnaire.	53.3% completed follow-up. Cohort: Increased NO2 (β = 0.15, $p < .001$), NOX (β = 0.05, $p < .001$), PM2.5 (β = 0.59 $p < .001$), and PM10 (β = 0.63, $p < .001$) and self-reported exposure to air pollution (β = 0.67, $p < .001$) was associated with increased sleep disturbance. Individual changes: Increased self-reported perceived air pollution air was not sig. associated with sleep disturbance.
Yu et al. (2017) China	Cohort longitudinal design. Follow-ups at: 1, 2, 3, 4, 5 and 6 years.	N = 3795 (females aged ≥55, males age ≥ 60) retired university faculty and staff.	Air pollution PM2.5.	Survey (2-items from the Fatigue in Medical Training Questionnaire).	23.3% completed follow-up. Increased PM2.5 was associated with increased sleep duration (β = 1.75, $p < .001$).

Yu et al. (2019) China	Cohort longitudinal design. Follow-up: 5 years.	N = 16889 (aged ≥ 18 M = 18.44 SD = 0.87; 32.36% female) university students.	Air pollution AQI, PM2.5, PM10, and NO2.	Survey (1-item from the Chinese Pittsburgh Sleep Quality Index).	77.8% completed follow-up. Increased AQI (β = 0.68, $p < .001$), PM2.5 (β = 0.55, $p < .01$), PM10 (β = 0.70, $p < .001$) and NO2 (β = 0.51, $p < .001$) was associated with reduced daily hours of sleep.

Adjustments:
An & Yu (2018): age, body mass index (BMI), self-rated mental health, self-rated physical health, drinking, smoking, percentage of rainy days in the last week, average wind speed and average daily temperature.
Li et al. (2020): a participant identifier, day of week, day of year, and humidity and temperature.
Lin et al. (2023): age, gender, ethnicity, education, employment, work schedule, alcohol intake, Townsend Deprivation Index, smoking status, coffee consumption, tea consumption, BMI, pain during the last month, depression and anxiety, nap habit, and night-time noise.
Liu et al. (2023b): age, gender, education, residence, marital status, disability, pension insurance, smoking status, alcohol consumption, type of heating and cooking fuel.
Martens et al. (2018): age, gender, smoking, education, neighbourhood income level, and year the measure was completed (baseline/follow-up).
Yu et al. (2017): age, marital status, annual household income, self-rated health, BMI, days in hospital or homecare in the last year, number of chronic diseases, smoking status, average daily temperature, average percentage of rainy days and wind speed in the last week.
Yu et al. (2019): age, BMI, self-rated physical health and mental health, drinking, smoking, temperature and rainy days in the last week.

Greenness

Astell-Burt & Feng (2020) Australia	Cohort longitudinal design. Follow-up: 3-9 years.	N = 38982 (aged ≥45; female 53.81%) from the Sax Institute's 45 and Up Study.	Green spaces, tree canopy and open grass.	Survey.	82% completed follow-up. Tree canopy (>30%) was sig. associated with a lower likelihood of insufficient sleep (OR = 0.87; CI: 0.75, 0.99). No other consistent association for green spaces, open grass exposure, or other low lying vegetation.

Liu et al. (2023b) China	Prospective cohort longitudinal design. Follow-ups at: 2, 4, 6, and 8 years.	N = 21878 (final data set; aged ≥ 45, M = 59.0, SD = 11.0; 52.5% female) from the China Health and Retirement Longitudinal Study.	Residential greenness.	Survey.	Greater greenness was sig. associated with reduced likelihood of sleep disorders (OR = 0.91; CI: 0.86, 0.96) and increased association with sleep duration (β = 0.09; CI: 0.05, 0.13).
Stenfors et al. (2023) Sweden	Cohort longitudinal design. Follow-ups at: 2 and 4 years.	N = 19375 (final data set; aged ≥ 18; 56.2% female) from the Swedish Longitudinal Occupational Survey of Health study.	Green spaces.	Survey (the Karolinska Sleep Questionnaire).	Green space at a buffer zone of 50m was associated with reduced sleep difficulties (β = -0.012 $p < .010$). No other consistent association for green space in zones of 100m, 300m, 500m and 1000m.

Adjustments:
Astell-Burt and Feng (2020): age, gender, couple status, education, economic status and annual household income.
Liu et al. (2023b): age, gender, education, residence, marital status, disability, pension insurance, smoking, alcohol, type of heating and cooking fuel.
Stenfors et al. (2023): age, gender, marital status, having children living at home or not, education, employment, disposable annual income, municipality size, neighbourhood mean annual income, physical activity and heavy drinking.

Neighbourhood characteristics

Hu et al. (2024) United States	Prospective cohort longitudinal design. Follow-up: 4 times in a year.	N = 511 (aged ≥18, M = 39.6, SD = 7.1; 100% female) from the Nurses' Health Study 3 Mobile Health Substudy.	Walkability.	Fitbit.	54.05% completed follow-up. Increased walkability was not significantly associated with sleep duration and not consistently associated with low or high sleep duration or efficiency.
Kim et al. (2022b) United States	Cohort longitudinal design. Follow-ups at: 4 and 6 years.	N = 1051 (aged ≥18, M = 54.6, SD = 16.5; 76.4% female). from the Pittsburgh Hill/Homewood Research on Eating, Shopping, and Health study.	Crime and neighbourhood disorder.	Actigraphy.	78% completed follow-up. Higher crime rates were associated with decreased sleep efficiency (RR = −0.55, $p < .05$) and increased insufficient sleep (RR =1.05, $p < .05$) and WASO (RD =3.73, $p < .05$). More neighbourhood disorder was associated with reduced sleep efficiency (RD = −0.46, $p < .050$). No sig. for insufficient sleep, total sleep and sleep efficiency, or WASO for each respective exposure.
Kim et al. (2023) United States	Cohort longitudinal design.	N = 1051 (aged ≥18, M = 54.6, SD = 16.5; 76.4% female). from the Pittsburgh	Crime, urban design, walkability and neighbourhood disorder.	Actigraphy.	78% completed follow-up. Better urban design was associated with reduced WASO (RD = −1.26, $p < .050$).

Follow-ups at: 4 and 6 years.	Hill/Homewood Research on Eating, Shopping, and Health study.	Higher crime rates were associated with increased risk of insufficient sleep (RR =1.05, $p < .050$) and WASO (RD = 3.62, $p < .050$). More neighbourhood disorder was associated with reduced sleep efficiency (RD = −0.46, $p < .050$). No sig. for insufficient sleep, total sleep and sleep efficiency, or WASO for each respective exposure. No sig. associations for walkability.

Adjustments:
Hu et al. (2024): age, race, education, marital status, employment, alcohol consumption, neighbourhood socioeconomic status, season, weekend versus weekday, night-time noise, light-at-night, temperature at night and greenness during wake.
Kim et al. (2022b): age, gender, education, marital status, family structure, and the number of years in the current neighbourhood.
Kim et al. (2023): age, gender, education, marital status, family structure, vehicle availability, and the number of years in the current neighbourhood.

Note. AHR = average hazard ratio; AQI = air quality index; β = standardized regression coefficient; BMI = body mass index; dB = decibel; CI: 95% confidence intervals; CO = carbon monoxide; NO2 = nitrogen dioxide; NOX = nitrogen oxides; O3 = ozone; PM2.5 = particulate matter with a diameter of 2.5 micrometers; PM10 = particulate matter with a diameter of 2.5 micrometers; RD = risk difference; RR = risk ratio; SO2 = sulfur dioxide; WASO = wake after sleep onset.

Noise pollution

Ten studies assessed noise pollution on sleep across different time points, including seven quasi-experimental and three cohort studies, with varied results between and within the studies. The quasi-experimental papers included interventions aimed at reducing noise pollution, where four of these found a positive change in sleep. Amundsen et al. (2013) observed that sleep disturbance significantly reduced in the intervention group following a facade insulation aimed to reduce traffic noise, while no changes were observed for the two control groups. Two related studies similarly found that sleep disturbance was significantly reduced after a road speed reduction (Brink et al., 2023) and after a night flight ban between 11pm and 5am (Schreckenberg et al., 2016). However, the latter study found no change in disturbance when falling asleep or in the early morning, where the flights were still running between 5am to 11pm. Nevertheless, this suggested improvement in nighttime sleep disturbance following the noise reducing interventions.

A study by Öhrström (2004) similarly reported improved sleep after the opening of a road tunnel, yet there were some inconsistencies across the different sleep measures. Based on the survey data, morning alertness increased and the frequency of taking more than 30 minutes to fall asleep decreased in the intervention group. Whilst the sleep logs showed reduced awakenings due to traffic noise, less difficulty returning back to sleep, and improved sleep quality. However, sleep quality showed no significant change in the survey data and taking more than 30 minutes to fall asleep showed no change from the sleep logs, suggesting differences between measures. Furthermore, difficulties initiating sleep, awakenings through night and being tired did not improve from either assessment.

Two other studies found no change in sleep. Xu et al. (2023) compared one week of having bedroom windows and doors remaining open or closed as usual and in the second

week closing them. This intervention had the shortest duration, and no significant improvement was observed for total sleep time, wake after sleep onset (WASO), sleep efficiency, and sleep quality. Another study by Nilsson and Berglund (2006) similarly found no significant effect for difficulties with falling asleep, awaken too early, and sleep quality after an installation of a road noise-barrier. In line with this, one study found that sleep worsened after a replaced or installed road noise barrier in three areas. Barros et al. (2024) found that in area 1 and 3, the participants were significantly more likely to lie awake in the morning, and area 1 and 2 found reductions in sleep duration. Additionally, there was no improvement for the time it took to fall asleep, and oversleeping or feeling rested in the morning in any areas.

In terms of the three cohort studies, these found a significant relationship between noise pollution and poorer sleep health. Martens et al. (2018) reported that both increased traffic noise exposure and self-reported noise had a small significant association with increased sleep disturbance. Additionally, they also observed within-participant changes, where increased self-reported noise exposure was associated with a corresponding modest increase in sleep disturbance at follow-up. A related study by Bozigar et al. (2023) similarly found that higher levels of airport noise modestly increased the likelihood of shorter sleep duration. Additionally, the outcome from Héritier et al. (2014) showed that higher levels of traffic noise annoyance had a small significant association with increased sleep disturbance at both baseline and follow-up, with a slight increase. Increased road traffic noise had a small indirect effect on this relationship. Taken together this suggested that increased noise could have adverse effects on sleep.

Overall, the cohort studies showed more consistent outcomes, marked by elevated noise being associated with worse sleep disturbance (Héritier et al., 2014; Martens et al., 2018) and duration (Bozigar et al., 2023). In contrast, although the majority of the

experimental studies found that the noise reducing interventions were linked to reduced sleep disturbance (Amundsen et al., 2013; Brink et al., 2023; Schreckenberg et al., 2016) and improved sleep patterns related to spending more time in bed asleep (Öhrström, 2004), they showed more variability. Specifically, different sleep measures within the same study yielded different outcomes (Öhrström, 2004), and interventions entailing installing or replacing noise barriers (Barros et al., 2024; Nilsson & Berglund, 2006), in addition to closing bedroom windows and doors coupled with a short timeframe (Xu et al., 2023) was not linked to improvements in sleep.

Air pollution

Seven cohort studies assessed air pollution, including nitrogen dioxide (NO2), nitrogen oxides (NOX), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), air quality index (AQI) and particulate matter with a diameter of 2.5 (PM2.5) and 10 (PM10), on sleep health over time. There were differences between and within the studies, in terms of sleep health parameters evaluated, types of air pollution assessed, and the strength and direction of the relationships.

Four studies demonstrated that higher levels of air pollution were linked to negative sleep health outcomes overtime. Yu et al. (2019) found that increased AQI, NO2, PM2.5 and PM10, were moderately associated with worsened sleep duration. Similar results were reported by Martens et al. (2018), which observed that higher levels of NO2, NOX, PM2.5, and PM10 had small to large associations on elevated sleep disturbance. However, although higher self-reported perceived levels of air pollution were significantly associated with worse sleep on the cohort level, this was not the case for within-person change in perceived exposure. Additionally, Lin et al. (2023) reported that increased concentration of CO, SO2, PM10, PM2.5, NO2, NOX and these air pollutants combined, were associated with risks

ranging from small to large for insomnia. This suggested that air pollutants might impose barriers on sleep health.

In accordance with this, Liu et al. (2023b) similarly observed a slight rise in the risk of sleep disorders and a small reduction in sleep duration with increased PM2.5 and PM10, thus further supporting the notion that air pollutants could result in declined sleep. However, they also found that increased NO3 was associated with a small elevation in sleep duration, yet no consistent association for this pollutant on risk of sleep disorders. Similarly, three other studies found a positive association between certain air pollutants and sleep health parameters. A related study by Yu et al. (2017) reported that PM2.5 was associated with a small increase in sleep duration, whilst Li et al. (2020) found that higher O3 was linked with a moderate increase of sleep duration, yet no consistent association for NO2, CO, O3, and SO2 with sleep latency, duration, efficiency and WASO. A similar study by An and Yu (2018) reported that PM2.5 was associated with a moderate increase in daily average hours of nighttime and daytime sleep combined.

These findings highlighted that NO2, NOX, and PM10 were generally associated with poorer sleep health and disturbed sleep patterns, marked by worsened sleep duration and increased risk of sleep disorders (Lin et al., 2023; Liu et al., 2023b; Martens et al., 2018; Yu et al., 2019). In contrast, PM2.5 showed a more variable relationship, yet the majority of the studies found that it was associated with worse sleep outcomes (Lin et al., 2023; Liu et al., 2023b; Martens et al., 2018; Yu et al., 2019). Additionally, the improvement noted from O3 (Li et al., 2020) and NO3 (Liu et al., 2023b) on sleep duration, and the no change on within-person change on perceived pollutants exposure (Martens et al., 2018), were only observed in three studies respectively.

Greenness

Three cohort studies assess green spaces on sleep at different time points. Although improvements in sleep health were observed, the strength of the relationships varied and there were mixed findings within and between the studies.

Liu et al. (2023b) found that greater greenness was associated with a slight increase in sleep duration and a small reduction in the likelihood of sleep disorders. This suggested that higher levels of greenness was associated with better sleep duration and a trend towards less sleep disorders. The study by Stenfors et al. (2023), similarly showed that green spaces were associated with a small reduction for sleep difficulties, yet only at a 50 meter buffer zone and not for zones exceeding this. Subsequently, this indicated that proximity to green spaces had a crucial role in influencing sleep. In contrast, Astell-Burt and Feng (2020) did not observe a significant association between sleep and green spaces, open grass exposure, or other low lying vegetation over time. However, tree canopy coverage exceeding 30%, slightly reduced the risk of insufficient sleep over time, highlighting the importance of spatial distribution.

Together, these papers showed that while green spaces contributed to better sleep, the proximity (Stenfors et al., 2023) and spread of greenness (Astell-Burt & Feng, 2020) appeared to have an important role for sleep health.

Neighbourhood characteristics

Three cohort studies examined physical neighbourhood characteristics on sleep health over time, which showed variable outcomes. Two papers assessed walkability on sleep, and neither of them found a significant association, indicating a limited impact of walkability. Specifically, Hu et al. (2024) found no significant association between walkability and low or high sleep duration or efficiency. A related study by Kim et al. (2023) similarly found no significant association between walkability and sleep efficiency, WASO or total sleep time.

In terms of crime and neighbourhood disorder on sleep, two papers assessed this. Kim et al. (2023) reported that higher crime rates were associated with a small and moderate increased risk for insufficient sleep and WASO respectively, and more neighbourhood disorder was related to a small reduction of sleep efficiency. They also found that better urban design, which included presence of graffiti, neighbourhood signage and landscaping, was linked to a small reduction of WASO, but no significant change was observed on the other sleep parameters. Additionally, the study by Kim et al. (2022b), which used the same sample with an added adjustment for vehicle availability, similarly found that neighbourhood disorder was linked to a small reduction in sleep efficiency, and that higher crime rates was associated with a small increase of WASO and risk of insufficient sleep. They also found a small reduction in risk of sleep efficiency with increased crime rates, which Kim et al. (2023) did not report. However, neither of the studies found that crime rates were significantly associated with total sleep time, or that neighbourhood disorder impacted insufficient sleep, total sleep time and WASO. This suggested that different neighbourhood characteristics impacted different facets of sleep health.

Although walkability did not appear to have an impact on sleep health (Hu et al., 2024; Kim et al., 2023), neighbourhood disorder and crime were linked to worse sleep, characterised by greater risk of poorer sleep and reduction in sleep efficiency (Kim et al., 2022b; Kim et al., 2023). Additionally, better neighbourhood design was observed to have a positive influence on sleep, yet this was only assessed with one study (Kim et al., 2023).

Quality appraisal

All studies rated high in methodological quality, yet there was variability across the dimensions. Specifically, for the k = 14 cohort studies assessed with CASP, k = 5 studies did not use validated measures to assess sleep and instead relied on items in a survey (Astell-Burt

& Feng, 2020; Bozigar et al., 2023; Hu et al., 2024; Liu et al., 2023b) or a bespoke unvalidated questionnaire (Lin et al., 2023; Appendix D). Additionally, in k = 4 studies, only 23.3% to 54.05% of the participants completed the follow-up (Bozigar et al., 2023; Hu et al., 2024; Martens et al., 2018; Yu et al., 2017). Two of these studies only included the participants that completed all-time points in the analysis (Hu et al., 2024; Yu et al., 2017) and the other two studies included all the participants' responses (Bozigar et al., 2023; Martens et al., 2018). However, for the latter two papers, one found that the participants who only completed baseline and the follow-up sample had similar scores at baseline (Martens et al., 2018), whereas the other study had the lowest response rate in the fourth wave (Bozigar et al., 2023). K = 2 studies did not explicitly state the number of participants at follow-up (Liu et al., 2023b; Stenfors et al., 2023), whilst another study had a short time duration of only six-weeks (Lin et al., 2023).

In terms of the populations, k = 7 studies used convenience samples, where k = 2 studies used university students (An & Yu, 2018; Yu et al., 2019), k = 1 study used retired faculty and staff from a university (Yu et al., 2017), k = 1 study had a small sample of participants with episodic migraines (Li et al., 2020), k = 1 with all female nurses (Bozigar et al., 2023), and k = 2 studies with predominantly females (Kim et al., 2022b; Kim et al., 2023). Subsequently, this might have limited the representativeness to other groups.

For the k = 7 quasi-experimental studies assessed with JBI (Appendix E), k = 3 studies did not use a control group (Brink et al., 2023; Schreckenberg et al., 2016; Xu et al., 2023). Additionally for all studies, it was unclear whether the outcomes were measured in a reliable way (Barros et al., 2024; Brink et al., 2023; Nilsson & Berglund, 2006; Schreckenberg et al., 2016) as the number of raters, their training and intra-rater reliability was not disclosed.

Discussion

The aim of this review was to assess longitudinal, including experimental, associations between the physical environment on sleep health in adults. In turn, this provided an understanding of temporal and causal relationships, which addressed a gap in the literature, where prior reviews have mainly focused on cross-sectional findings.

Twenty-one papers were identified, which examined different facets of the physical environment on sleep health over time. Overall, fourteen studies observed that increased noise (Bozigar et al., 2023; Héritier et al., 2014; Martens et al., 2018) and air pollution (Lin et al., 2023; Liu et al., 2023b; Martens et al., 2018; Yu et al., 2019), and adverse neighbourhood characteristics, including crime and disorder (Kim et al., 2022b; Kim et al., 2023), were associated with negative sleep outcomes. In contrast, green spaces (Astell-Burt & Feng, 2020; Liu et al., 2023b; Stenfors et al., 2023), better urban design (Kim et al., 2023), and interventions aimed to reduce noise (Amundsen et al., 2013; Brink et al., 2023; Schreckenberg et al., 2016; Öhrström, 2004) were associated with improved sleep health. In line with the socioecological model of sleep health (Grandner, 2019), this highlighted how the broader contextual long-term impact of the physical environment acted as a protective or risk factor.

In terms of noise pollution**,** this showed that airport or road traffic noise was linked to poorer sleep health at follow-up, whilst interventions aimed at reducing noise demonstrated improved sleep. This was in accordance with Hunter and Hayden (2018) and Smith et al. (2022) narrative review and systematic review respectively. However, as they mainly included studies that were cross-sectional in nature, the present review added to the literature by asserting the long-term effects for sleep change. In turn, this positioned noise pollution as an adverse factor on sleep over time, potentially as a result of activating the body's stress

response that interfered with sleep architecture (Liu et al., 2021). Nevertheless, although the cohort studies showed consistent findings between elevated noise and worse sleep over time (Bozigar et al., 2023; Héritier et al., 2014; Martens et al., 2018), the experimental studies showed more variability (Amundsen et al., 2013; Barros et al., 2024; Brink et al., 2023; Nilsson & Berglund, 2006; Öhrström, 2004; Schreckenberg et al., 2016; Xu et al., 2023).

Three experimental papers showed no change in sleep health parameters after interventions aimed to reduce road traffic noise (Xu et al., 2023; Barros et al., 2024; Nilsson & Berglund, 2006), where one of these studies also found worsened sleep (Barros et al., 2024). However, one of these papers had a small sample and the intervention length was short (Xu et al., 2023), whilst the other two studies used a bespoke unvalidated questionnaire (Nilsson & Berglund, 2006) or a survey (Barros et al., 2024) to assess sleep. In contrast, the other included studies with a longer intervention duration, larger samples and/or validated sleep questionnaires found improvement in sleep following noise reducing interventions (e.g. Amundsen et al., 2013; Bozigar et al., 2023). Additionally, at follow-up, these three studies reported that the noise was still above the level recommended by the WHO (Berglund et al., 2020; WHO, 2010), which could have resulted in suboptimal impact on sleep.

Despite these deviations, the majority of the included studies suggested that noise was linked to worse sleep (Bozigar et al., 2023; Héritier et al., 2014; Martens et al., 2018) and that noise reducing interventions improved sleep (Amundsen et al., 2013; Brink et al., 2023; Öhrström, 2004; Schreckenberg et al., 2016). However, a small sample, short intervention length (Xu et al., 2023) and using bespoke unvalidated sleep measures (Nilsson & Berglund, 2006; Barros et al., 2024) resulted in varied outcomes.

Similar to noise, most of the studies reported that higher levels of air pollution had a detrimental impact on sleep health outcomes over time. This aligned with the systematic

review by Zhao et al. (2023), which linked air pollution to risk of sleep disorders, yet they did not assess the long-term implication of this. Subsequently, the present review added to the understanding of the cumulative long-term impact of air pollution on sleep health. A possible process for this could have been that air pollution entering the brain has been proposed to reduce serotonin levels, which regulate sleep-wake cycles, leading to difficulties with falling and staying asleep (Liu et al., 2021). Alternatively, air pollution entering the respiratory system might result in airflow obstruction or inflammation, resulting in awakenings through night (Liu et al., 2021). However, some of the papers showed mixed or opposing findings, where increased O3 (Li et al., 2020), NO3, (Liu et al., 2023b) and PM2.5 (An & Yu, 2018; Yu et al., 2017) were observed to be associated with improved sleep duration or combined day and night sleep time, similar to the findings from the systematic reviews by Hunter and Hayden (2018) and Liu et al. (2020).

In terms of the contrasting findings, a possible explanation for this could have been that some of the studies used convenience samples, including retirees (Yu et al., 2017), university students (An & Yu, 2018), or a small sample diagnosed with migraines (Li et al., 2020), which could have provided biassed outcomes due to poor representation of the general population (Jager et al., 2017). Although one study used a more representative sample (Liu et al., 2023b), they did not use a validated sleep measure, where the other included studies found negative effects using validated measures (e.g. Martens et al., 2018; Yu et al., 2019). Moreover, only one of the included studies assessed O3 with a small sample (Li et al., 2020), yet a prior study with a larger sample using a similar objective sleep measure found a negative impact from O3 (Zhou et al., 2023). Nevertheless, the studies generally found that increased NO2, NOX, CO, SO2, and PM10 were associated with poorer sleep health (Lin et al., 2023; Liu et al., 2023b; Martens et al., 2018; Yu et al., 2019), whilst PM2.5 showed a

little more variability (Lin et al., 2023; Liu et al., 2023b; Martens et al., 2018; Yu et al., 2019), which might have stemmed from methodological differences.

In relation to physical neighbourhood characteristics, including urban design, walkability, neighbourhood disorder and crime, showed variable outcomes on sleep health over time. Whilst some prior research has found that walkability has been associated with better sleep (Smith et al., 2017), none of the papers found an impact of walkability on sleep health (Hu et al., 2024; Kim et al., 2023). In turn, this might have been a result of competing sources, whilst better walkability has been found to be linked with improved sleep (Adjaye-Gbewonyo et al., 2023; Nam et al., 2018), it might also co-occur with exposure to air and noise pollution and adverse neighbourhood characteristics, which could impair sleep (Billings et al., 2020; Hale et al., 2020; Hunter & Hayden, 2018). Research has supported this notion, as walking in a green environment has been found to improve sleep but not walking in a built environment (Gladwell et al., 2016). Subsequently, this highlighted the importance of the surrounding environment, including the presence of green spaces or levels of neighbourhood disorder, which might be more critical than walkability itself.

Neighbourhood disorder and crime were other factors examined in the papers, where higher levels of these were associated with worse sleep, whilst better urban design was linked to improved sleep (Kim et al., 2022b; Kim et al., 2023). A mechanism behind this could have been that disorder and crime activated the sympathetic nervous system and associated stress-related responses, resulting in arousal and therefore impaired sleep (Mellman et al., 2018). This was in accordance with the literature, which linked neighbourhood disorder, crime, (DeSantis et al., 2013; Kim et al., 2022a; Richardson, 2021) and poorer urban design with worse sleep (Sutil et al., 2024), yet this has mainly been examined cross-sectionally. Subsequently, the present review contributed to the literature by highlighting the long-term

effects. However, this should be interpreted with caution due to the small number of papers and that they used the same sample yet adjusted for different factors.

Extending the focus to greenness, the studies assessing the longitudinal impact of factors related to green spaces observed positive associations on sleep health, which asserted it as a protective factor. This was in accordance with the systematic review by Shin et al. (2020), which reported a positive relationship between exposure to green spaces and sleep, yet they mainly assessed studies that were cross-sectional or interventions assessing walking programs in green environments. In comparison, the present review's findings highlighted how green spaces influenced sleep over time and successively added to the evidence to patterns of causality. A potential process for this could have been that green spaces and vegetation reduced stress and promoted relaxation (WHO, 2016), which decreased arousal and thus encouraged sleep (Grigsby-Toussaint et al., 2015).

Although greater greenness was associated with better sleep, distribution of 30% and above (Astell-Burt & Feng, 2020), in addition to proximity within 50 meters (Stenfors et al., 2023) emerged as important factors. Prior cross-sectional research has supported this stance, where a study by Chum et al. (2015) found no relationship between sleep duration and green spaces within a 250 meter buffer zone. However, even though one of the included papers found that distribution of tree canopy coverage exceeding 30% was associated with better sleep health, they did not find this effect for other more low-lying vegetation (Astell-Burt & Feng, 2020). This might have been due to the satellite images of grass and vegetation being obscured below the tree cover. In turn, this added nuance, by highlighting the importance of widespread availability (Stenfors et al., 2023) and spatial distribution (Astell-Burt & Feng, 2020) of green spaces as important factors for promoting sleep health.

Strengths and Limitations

Strengths of the review encompassed that a protocol was pre-registered, the PRISMA guidelines were adhered to, and the review met the CASP systematic review checklist criterions (Appendix F), except for the one related to meta-regression and associated sensitivity analyses. The diversity of the physical environmental factors, sleep health parameters and measures, made it difficult to carry out a meta-analysis (McKenzie & Brennan, 2019) and therefore a narrative synthesis was selected, as this allowed to interpret a broad topic (Greenhalgh et al., 2018).

Three databases were searched without limitation to year of publication, which could have reduced bias by ensuring that relevant studies were included (Aali & Shokraneh, 2021). However, a MeSH-terms search strategy was not employed, which has been proposed to provide a higher proportion of relevant studies compared to text-word strategy (DeMars & Perruso, 2022). Additionally, backward and forward citation searchers was not conducted, which potentially could have omitted relevant papers (Gusenbauer & Gauster, 2025). Nevertheless, a subject specialist librarian was consulted to ensure a robust search strategy, and several search terms were included, which captured a wide array of papers from different countries assessing various physical environmental factors on sleep over time, which mitigated Western bias (Phillips & Greene, 2022).

Only published papers in English were included, which could have introduced publication bias, as those with a significant effect have been proposed to be more likely to be published (Franco et al., 2014) and papers not yet published could have been left out (Pappas & Williams, 2011). Additionally, publications with negative outcomes have been found to be less likely to be published in English and more probable to be published in the local language (Heres et al., 2004), hence some studies could have been omitted. Nevertheless, a notable

strength was that an independent researcher assessed a sub-sample of the papers during the initial selection process and risk of bias assessment, where all studies were rated highly. This showed high inter-rater reliability, which supported the accuracy of the results (McHugh, 2012).

Although the quality appraisal was high across studies, examination of the profile of quality appraisal characteristics revealed a more nuanced pattern. This highlighted heterogeneity between the studies, in terms of physical environmental factors assessed, measures of sleep health and sleep parameters examined, as expected due to the broad topic. Majority of the studies used self-reported sleep measures, and some did not rely on validated measures. None of the studies used polysomnography, which has been considered the gold standard measure of sleep (Rundo & Downey, 2019). However, four studies objectively measured sleep, with either actigraphy or a Fitbit.

The follow-up period of some studies was short and some also used convenience samples, which limited external validity. Additionally, two papers used the same sample, yet they adjusted for different factors, and only one study assessed urban design. Hence, interpretations should be approached with caution. Nevertheless, all studies were longitudinal, with either a cohort or quasi-experimental design, which addressed a gap in the literature by widening the understanding of temporal and causal relationships, where prior reviews have mainly focused on cross-sectional outcomes.

Implications

Sleep was observed to be influenced by broader longitudinal effects of physical environmental characteristics, widening the understanding of sleep not being solely contingent on individual-level aspects of interpersonal factors or behaviours. While physical environmental conditions could differ across countries, the physiological stress responses

from these, which could impact sleep, have been evolutionarily conserved (Godoy et al., 2018), making the findings relevant across the globe. In line with the upstream-downstream metaphor (McMahon, 2022), this supported taking a wider upstream preventative perspective to address underlying root causes that could promote or suppress sleep. In conjunction with this, considering that sleep spans a concern across sectors as a pivotal determinant for mental and physical health (Czeisler, 2015), this aligned with adopting a public health-informed approach with a systemic view of how sleep could be addressed (e.g. Harper, 2017).

Based on this, Clinical Psychologists could contribute to interventions targeting the physical environment by embedding in cross disciplinary collaboration on initiatives with relevant stakeholders such as city planners, policymakers, other health practitioners, local and national authorities, and community members. In turn, this could contribute to a psychological perspective on physical environmental characteristics that give rise to or mitigate poor sleep health and formulations to understand their relationships. Additionally, drawing on public health data could inform these formulations and decision-making processes. In parallel, within these forums Clinical Psychologists could also advocate for policy changes to address the broader physical environment through reforms and redistribution of resources (e.g., Corcoran, 2023).

Several different interventions and policies could target green spaces, neighbourhood disorder, crime and design, and noise and air pollution to enhance sleep health. This might involve mitigating noise pollution through regulating noise and flow from traffic, soundproofing and curfews for roads and aircrafts, and implementing speed regulations. Additionally, air quality could be improved through regulations and enforced taxes or incentives to reduce emissions, tightening control on sources for industrial pollution and traffic emissions, and improving public transport and cycling infrastructure. Other interventions could entail building accessible green spaces, increasing tree lines and number

of parks, in addition to refining urban planning and design, investing in people and the maintenance of public spaces. In turn, this might result in a healthier population.

Direction for Further Research

More longitudinal data is needed that assesses noise and air pollution, green spaces, physical neighbourhood characteristics, including urban design, crime, disorder and walkability, on sleep health, to build up the evidence base further. Future research should also consider examining interventions and policy changes that enhances the physical environment, to assess potential improvements on sleep health. Additionally, sleep should be assessed objectively with polysomnography or another objective measure. In turn, this could provide reliable and accurate data, by reducing potential self-reported biases and increasing the validity of the data. Lastly, investigating both individual and the co-occurrence of physical environmental factors could allow for a comprehensive understanding of distinct effects and how they interact in shaping sleep outcomes.

Conclusion

This systematic review assessed longitudinal associations between the physical environment on sleep health in adults. Twenty-one studies, cohort and experimental, were identified. Fourteen of these papers observed that increased noise and air pollution, and adverse physical neighbourhood characteristics were negatively associated with sleep health over time, whereas green spaces, better urban design, and interventions aimed to reduce noise were linked to healthier sleep. However, walkability was not associated with sleep. Moreover, some of the physical environmental categories had very few studies and some studies found mixed or deviating findings, possibly due to methodological differences. Nevertheless, the overall findings suggested that green spaces and better urban design acted as protective factors for sleep, whilst air and noise pollution, and adverse physical neighbourhood

characteristics, including crime and disturbance, operated as risk factors. In turn, this could inform preventative interventions and policies to enhance sleep health, where future research is urged to examine the outcome of these.

Reference

Aali, G., & Shokraneh, F. (2021). No limitations to language, date, publication type, and publication status in search step of systematic reviews. *Journal of Clinical Epidemiology*, *133*. https://doi.org/10.1016/j.jclinepi.2021.02.002

Adjaye-Gbewonyo, D., Ng, A. E., Jackson, C. L., & Johnson, D. A. (2023). The perceived neighborhood walking environment and self-reported sleep health in a nationally representative sample of the United States. *Health & Place*, *83*, 103066. https://doi.org/10.1016/j.healthplace.2023.103066

An, R., & Yu, H. (2018). Impact of ambient fine particulate matter air pollution on health behaviors: A longitudinal study of university students in Beijing, China. *Public Health*, *159*, 107-115. https://doi.org/10.1016/j.puhe.2018.02.007

Amundsen, A. H., Klæboe, R., & Aasvang, G. M. (2013). Long-term effects of noise reduction measures on noise annoyance and sleep disturbance: The Norwegian facade insulation study. *The Journal of the Acoustical Society of America*, *133*(6), 3921-3928. https://doi.org/10.1121/1.4802824

Astell-Burt, T., & Feng, X. (2020). Does sleep grow on trees? A longitudinal study to investigate potential prevention of insufficient sleep with different types of urban green space. *SSM-population Health*, *10*, 100497. https://doi.org/10.1016/j.ssmph.2019.100497

Barros, A., Kampen, J. K., & Vuye, C. (2024). Noise barriers as a mitigation measure for highway traffic noise: Empirical evidence from three study cases. *Journal of Environmental Management*, *367*, 121963. https://doi.org/10.1016/j.jenvman.2024.121963

Berglund, B., Lindvall, T., & Schwela, D. H. (2020). *Guidelines for community noise.* World Health Organization, Geneva. https://www.who.int/publications/i/item/a68672

Billings, M. E., Hale, L., & Johnson, D. A. (2020). Physical and social environment relationship with sleep health and disorders. *Chest*, *157*(5), 1304-1312. https://doi.org/10.1016/j.chest.2019.12.002

Bozigar, M., Huang, T., Redline, S., Hart, J. E., Grady, S. T., Nguyen, D. D., James, P., Nicholas, B., Levy, J. I., Laden, F., & Peters, J. L. (2023). Associations between aircraft noise exposure and self-reported sleep duration and quality in the United States-based prospective Nurses' Health Study Cohort. *Environmental Health Perspectives*, *131*(4), 047010. https://doi.org/10.1289/EHP10959

Brink, M., Mathieu, S., Artho, J., & Rüttener, S. (2023). Effects of traffic speed reduction interventions on noise-induced annoyance and self--reported sleep disturbances: A longitudinal study in Zurich. *Institute of Noise Control Engineering, 265*(5), 2249-2258. https://doi.org/10.3397/IN_2022_0323

Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter?. *Sleep*, *37*(1), 9-17. https://doi.org/10.5665/sleep.3298

Chum, A., O'Campo, P., & Matheson, F. (2015). The impact of urban land uses on sleep duration and sleep problems. *The Canadian Geographer/Le Géographe canadien*, *59*(4), 404-418. https://doi.org/10.1111/cag.12202

Cohen, J. (1960). A cofficient of agreement for nominal scales. *Educational and psychological measurement*, *20*(1), 37-46. https://doi.org/10.1177/001316446002000104

Corcoran, R. (2023). Poverty, ACEs and stigmatised places: The application of psychology to the challenges of disadvantage. *Psychology and Psychotherapy: Theory, Research and Practice*, *96*(3), 577-589. https://doi.org/10.1111/papt.12457

Critical Appraisal Skills Programme. (2022). *CASP checklists.* https://casp-uk.net/casp-tools-checklists/

Czeisler, C. A. (2015). Duration, timing and quality of sleep are each vital for health, performance and safety. *Sleep Health: Journal of the National Sleep Foundation*, *1*(1), 5-8. https://doi.org/10.1016/j.sleh.2014.12.008

DeMars, M. M., & Perruso, C. (2022). MeSH and text-word search strategies: precision, recall, and their implications for library instruction. *Journal of the Medical Library Association*, *110*(1), 23. https://doi.org/10.5195/jmla.2022.1283

DeSantis, A. S., Diez Roux, A. V., Moore, K., Baron, K. G., Mujahid, M. S., & Nieto, F. J. (2013). Associations of neighborhood characteristics with sleep timing and quality: The Multi-Ethnic Study of Atherosclerosis. *Sleep*, *36*(10), 1543-1551. https://doi.org/10.5665/sleep.3054

Franco, A., Malhotra, N., & Simonovits, G. (2014). Publication bias in the social sciences: Unlocking the file drawer. *Science*, *345*(6203), 1502-1505. https://doi.org/10.1126/science.1255484

Grandner, M. A. (2019). *Sleep and health* (pp. 45-53). Academic Press.

Greenhalgh, T., Thorne, S., & Malterud, K. (2018). Time to challenge the spurious hierarchy of systematic over narrative reviews?. *European Journal of Clinical Investigation*, *48*(6). https://doi.org/10.1111/eci.12931

George, P. P., Molina, J. A. D., & Heng, B. H. (2014). The methodological quality of systematic reviews comparing intravitreal bevacizumab and alternates for neovascular age related macular degeneration: A systematic review of reviews. *Indian Journal of Ophthalmology*, *62*(7), 761-767. https://doi.org/10.4103/0301-4738.138615

Gladwell, V. F., Kuoppa, P., Tarvainen, M. P., & Rogerson, M. (2016). A lunchtime walk in nature enhances restoration of autonomic control during night-time sleep: Results from a preliminary study. *International Journal of Environmental Research and Public Health*, *13*(3), 280. https://doi.org/10.3390/ijerph13030280

Godoy, L. D., Rossignoli, M. T., Delfino-Pereira, P., Garcia-Cairasco, N., & de Lima Umeoka, E. H. (2018). A comprehensive overview on stress neurobiology: Basic concepts and clinical implications. *Frontiers in Behavioral Neuroscience*, *12*, 127. https://doi.org/10.3389/fnbeh.2018.00127

Grigsby-Toussaint, D. S., Turi, K. N., Krupa, M., Williams, N. J., Pandi-Perumal, S. R., & Jean-Louis, G. (2015). Sleep insufficiency and the natural environment: Results from the US Behavioral Risk Factor Surveillance System survey. *Preventive Medicine*, *78*, 78-84. https://doi.org/10.1016/j.ypmed.2015.07.011

Gusenbauer, M., & Gauster, S. P. (2025). How to search for literature in systematic reviews and meta-analyses: A comprehensive step-by-step guide. *Technological Forecasting and Social Change*, *212*, 123833. https://doi.org/10.1016/j.techfore.2024.123833

Hale, L., Troxel, W., & Buysse, D. J. (2020). Sleep health: An opportunity for public health to address health equity. *Annual Review of Public Health*, *41*(1), 81-99. https://doi.org/10.1146/annurev-publhealth-040119-094412

Han, K. S., Kim, L., & Shim, I. (2012). Stress and sleep disorder. *Experimental Neurobiology*, *21*(4), 141. https://doi.org/10.5607/en.2012.21.4.141

Harper, D. (2017). The promise (and potential pitfalls) of a public health approach in clinical psychology. *Clinical Psychology Forum*, 297, 23-32. https://doi.org/10.53841/bpscpf.2017.1.297.23

Heres, S., Wagenpfeil, S., Hamann, J., Kissling, W., & Leucht, S. (2004). Language bias in neuroscience—is the Tower of Babel located in Germany?. *European Psychiatry*, *19*(4), 230-232. https://doi.org/10.1016/j.eurpsy.2003.09.011

Héritier, H., Vienneau, D., Frei, P., Eze, I. C., Brink, M., Probst-Hensch, N., & Röösli, M. (2014). The association between road traffic noise exposure, annoyance and health-related quality of life (HRQOL). *International Journal of Environmental Research and Public Health*, *11*(12), 12652-12667. https://doi.org/10.3390/ijerph111212652

Hu, C. R., Wilt, G. E., Roscoe, C., Iyer, H. S., Kessler, W. H., Laden, F., Chavarro, J. E., Coull, B., Redline, S., James, P., & Hart, J. E. (2024). Associations of seasonally available global positioning systems-derived walkability and objectively measured sleep in the Nurses' Health Study 3 Mobile Health Substudy. *Environmental Epidemiology*, *8*(6), e348. https://doi.org/10.1097/EE9.0000000000000348

Hunter, J. C., & Hayden, K. M. (2018). The association of sleep with neighborhood physical and social environment. *Public Health*, *162*, 126-134. https://doi.org/10.1016/j.puhe.2018.05.003

Law, M., Cooper, B., Strong, S., Stewart, D., Rigby, P., & Letts, L. (1996). The person-environment-occupation model: A transactive approach to occupational performance. *Canadian Journal of Occupational Therapy*, *63*(1), 9-23. https://doi.org/10.1177/000841749606300103

Jager, J., Putnick, D. L., & Bornstein, M. H. (2017). More than just convenient: The scientific merits of homogeneous convenience samples. *Monographs of the Society for Research in Child Development*, *82*(2), 13-30. https://doi.org/10.1111/mono.12296

Joanna Briggs Institute. (2020). *Checklist for quasi-experimental studies (non-randomized experimental studies).* https://jbi.global/sites/default/files/2020-07/Checklist_for_Quasi-Experimental_Appraisal_Tool.pdf

Johnson, D. A., Al-Ajlouni, Y. A., & Duncan, D. T. (2019). Connecting neighbourhoods and sleep health. In D. T. Duncan, I. Kawachi & S. Redline (Eds.), *The social epidemiology of sleep* (pp. 409-431). Oxford University Press.

Johnson, D. A., Billings, M. E., & Hale, L. (2018). Environmental determinants of insufficient sleep and sleep disorders: Implications for population health. *Current Epidemiology Reports*, *5*, 61-69. https://doi.org/10.1007/s40471-018-0139-y

Johnson, D. A., Lisabeth, L., Hickson, D., Johnson-Lawrence, V., Samdarshi, T., Taylor, H., & Diez Roux, A. V. (2016). The social patterning of sleep in African Americans: Associations of socioeconomic position and neighborhood characteristics with sleep in the Jackson Heart Study. *Sleep*, *39*(9), 1749-1759. https://doi.org/10.5665/sleep.6106

Kim, B., Branas, C. C., Rudolph, K. E., Morrison, C. N., Chaix, B., Troxel, W. M., & Duncan, D. T. (2022a). Neighborhoods and sleep health among adults: A systematic review. *Sleep Health*, *8*(3), 322-333. https://doi.org/10.1016/j.sleh.2022.03.005

Kim, B., Troxel, W. M., Dubowitz, T., Hunter, G. P., Ghosh-Dastidar, B., Chaix, B., Rudolph, K. E., Morrison, C. N., Branas, C. C., & Duncan, D. T. (2022b). Mediating role of psychological distress in the associations between neighborhood social environments and sleep health. *Sleep*, *45*(8), zsac087. https://doi.org/10.1093/sleep/zsac087

Kim, B., Troxel, W. M., Dubowitz, T., Hunter, G. P., Ghosh-Dastidar, B., Chaix, B., Rudolph, K. E., Morrison, C. N., Branas, C. C., & Duncan, D. T. (2023). Neighborhood built environment and sleep health: A longitudinal study in low-income and predominantly African-American neighborhoods. *American Journal of Epidemiology*, *192*(5), 736-747. https://doi.org/10.1093/aje/kwad016

Li, W., Bertisch, S. M., Mostofsky, E., Vgontzas, A., & Mittleman, M. A. (2020). Associations of daily weather and ambient air pollution with objectively assessed sleep duration and fragmentation: A prospective cohort study. *Sleep Medicine*, *75*, 181-187. https://doi.org/10.1016/j.sleep.2020.06.029

Lin, Y., Gao, Y., Sun, X., Wang, J., Ye, S., Wu, I. X., & Xiao, F. (2023). Long-term exposure to ambient air pollutants and their interaction with physical activity on insomnia: A prospective cohort study. *Environmental Research*, *224*, 115495. https://doi.org/10.1016/j.envres.2023.115495

Liu, F., Zhou, F., Zhang, K., Wu, T., Pan, M., Wang, X., Tong, J., Chen, Z., & Xiang, H. (2023b). Effects of air pollution and residential greenness on sleep disorder: A 8-year nationwide cohort study. *Environmental Research*, *220*, 115177. DOI: https://doi.org/10.1016/j.envres.2022.115177

Liu, J., Ghastine, L., Um, P., Rovit, E., & Wu, T. (2021). Environmental exposures and sleep outcomes: A review of evidence, potential mechanisms, and implications. *Environmental Research*, *196*, 110406. https://doi.org/10.1016/j.envres.2020.110406

Liu, J., Wu, T., Liu, Q., Wu, S., & Chen, J. C. (2020). Air pollution exposure and adverse sleep health across the life course: A systematic review. *Environmental Pollution*, *262*, 114263. https://doi.org/10.1016/j.envpol.2020.114263

Liu, X., Hong, C., Liu, Z., Fan, L., Yin, M., Chen, Y., Ren, X., & Gu, X. (2023a). Association of sleep disorders with asthma: A meta-analysis. *British Medical Journal Open Respiratory Research*, *10*(1), e001661. https://doi.org/10.1136/bmjresp-2023-001661

Lund, C., Brooke-Sumner, C., Baingana, F., Baron, E. C., Breuer, E., Chandra, P., Haushofer, J., Herrman, H., Jordans, M., Kieling, C., Medina-Mora, M. E., Morgan, E., Omigbodun, O., Tol, W., Patel, V., & Saxena, S. (2018). Social determinants of mental disorders and the Sustainable Development Goals: A systematic review of reviews. *The Lancet Psychiatry*, *5*(4), 357-369. https://doi.org/10.1016/s2215-0366(18)30060-9

Marco, M., Gracia, E., Tomás, J. M., & López-Quílez, A. (2015). Assessing neighborhood disorder: Validation of a three-factor observational scale. *The European Journal of Psychology Applied to Legal Context*, *7*(2), 81-89. https://doi.org/10.1016/j.ejpal.2015.05.001

Martens, A. L., Reedijk, M., Smid, T., Huss, A., Timmermans, D., Strak, M., Swart, W., Lenters, V., Kromhout, H., Verheij, R., Slottje, P., & Vermeulen, R. C. (2018). Modeled and perceived RF-EMF, noise and air pollution and symptoms in a population cohort. Is perception key in predicting symptoms?. *Science of the Total Environment*, *639*, 75-83. https://doi.org/10.1016/j.scitotenv.2018.05.007

McEwen, B. S., & Stellar, E. (1993). Stress and the individual: Mechanisms leading to disease. *Archives of Internal Medicine*, *153*(18), 2093-2101. https://doi.org/10.1001/archinte.1993.00410180039004

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica*, *22*(3), 276-282 https://doi.org/10.11613/BM.2012.031

McMahon, N. E. (2022). Framing action to reduce health inequalities: What is argued for through use of the 'upstream–downstream'metaphor?. *Journal of Public Health*, *44*(3), 671-678. https://doi.org/10.1093/pubmed/fdab157

McKenzie, J. E., & Brennan, S. E. (2019). Synthesizing and presenting findings using other methods. In J. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. Page & J. Welch (Ed.). *Cochrane handbook for systematic reviews of interventions* (2nd ed. pp. 321-346). John Wiley & Sons. https://training.cochrane.org/handbook/current/chapter-12

Mellman, T. A., Bell, K. A., Abu-Bader, S. H., & Kobayashi, I. (2018). Neighborhood stress and autonomic nervous system activity during sleep. *Sleep*, *41*(6), zsy059. https://doi.org/10.1093/sleep/zsy059

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine*, *151*(4), 264-269. https://doi.org/10.1371/journal.pmed.1000097

Morin, C. M., & Benca, R. (2012). Chronic insomnia. *The Lancet*, *379*(9821), 1129-1141. https://doi.org/10.1016/S0140-6736(11)60750-2

Muzet, A. (2007). Environmental noise, sleep and health. *Sleep medicine reviews*, *11*(2), 135-142. https://doi.org/10.1016/j.smrv.2006.09.001

Nam, S., Whittemore, R., Jung, S., Latkin, C., Kershaw, T., & Redeker, N. S. (2018). Physical neighborhood and social environment, beliefs about sleep, sleep hygiene behaviors, and sleep quality among African Americans. *Sleep Health*, *4*(3), 258-264. https://doi.org/10.1016/j.sleh.2018.03.002

Nilsson, M. E., & Berglund, B. (2006). Noise annoyance and activity disturbance before and after the erection of a roadside noise barrier. *The Journal of the Acoustical Society of America*, *119*(4), 2178-2188. https://doi.org/10.1121/1.2169906

Öhrström, E. (2004). Longitudinal surveys on effects of changes in road traffic noise: Effects on sleep assessed by general questionnaires and 3-day sleep logs. *Journal of Sound and Vibration*, *276*(3-5), 713-727. https://doi.org/10.1016/j.jsv.2003.08.038

Pappas, C., & Williams, I. (2011). Grey literature: Its emerging importance. *Journal of Hospital Librarianship*, *11*(3), 228-234. https://doi.org/10.1080/15323269.2011.587100

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., MayoWilson, E., McDonald, S., & McGuinness, L. A. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *British Medical Journal*, *372*. https://doi.org/10.1136/bmj.n71

Pelgrims, I., Devleesschauwer, B., Keune, H., Nawrot, T. S., Remmen, R., Saenen, N. D., Thomas, I., Gorasso, V., Van der Heyden, J., De Smedt, D., & De Clercq, E. (2022). Validity of self-reported air pollution annoyance to assess long-term exposure to air pollutants in Belgium. *Environmental Research*, *210*, 113014. https://doi.org/10.1016/j.envres.2022.113014

Perron, S., Plante, C., Ragettli, M. S., Kaiser, D. J., Goudreau, S., & Smargiassi, A. (2016). Sleep disturbance from road traffic, railways, airplanes and from total environmental noise levels in Montreal. *International Journal of Environmental Research and Public Health*, *13*(8), 809. https://doi.org/10.3390/ijerph13080809

Phillips, B. J., & Greene, K. T. (2022). Where is conflict research? Western bias in the literature on armed violence. *International Studies Review*, *24*(3), viac038. https://doi.org/10.1093/isr/viac038

Pinter-Wollman, N., Jelić, A., & Wells, N. M. (2018). The impact of the built environment on health behaviours and disease transmission in social systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1753), 20170245. https://doi.org/10.1098/rstb.2017.0245

Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Britten, N., Roen, K., & Duff, S. (2006) *Guidance on the conduct of narrative synthesis in systematic Reviews: A product from the ESRC Methods Programme*. Version, 1(1), b92. Lancaster University. https://doi.org/10.13140/2.1.1018.4643

Richardson, A. S., Troxel, W. M., Ghosh-Dastidar, M., Hunter, G. P., Beckman, R., Collins, R., Holliday, S. B., Nugroho, A., Hale, L., Buysse, D., Buman, M. P., & Dubowitz, T. (2021). Violent crime, police presence and poor sleep in two low-income urban predominantly Black American neighbourhoods. *Journal of Epidemiology and Community Health*, *75*(1), 62-68. https://doi.org/10.1136/jech-2020-214500

Robbins, L. (2019). Migraine treatment: What's old, what's new. *Practical Pain Management Journal*, *17*, 5. https://www.medcentral.com/pain/chronic/migraine-treatment-what-old-what-new

Rundo, J. V., & Downey III, R. (2019). Polysomnography. In K. H. Levin & P. Chauvel (Eds. Vol. 160), *Handbook of Clinical Neurology* (pp. 381-392). Elsevier. https://doi.org/10.1016/B978-0-444-64032-1.00025-4

Schreckenberg, D., Belke, C., Faulbaum, F., Guski, R., Möhler, U., & Spilski, J. (2016). Effects of aircraft noise on annoyance and sleep disturbances before and after

expansion of Frankfurt airport-results of the NORAH study, WP 1'annoyance and quality of life'. *Noise Control Engineering Journal, 253*(7), 997-1006. https://www.ingentaconnect.com/content/ince/incecp/2016/00000253/00000007/art00014

Scott, A. J., Webb, T. L., Martyn-St James, M., Rowse, G., & Weich, S. (2021). Improving sleep quality leads to better mental health: A meta-analysis of randomised controlled trials. *Sleep Medicine Reviews*, *60*, 101556. https://doi.org/10.1016/j.smrv.2021.101556

Shin, J. C., Parab, K. V., An, R., & Grigsby-Toussaint, D. S. (2020). Greenspace exposure and sleep: A systematic review. *Environmental Research*, *182*, 109081. https://doi.org/10.1016/j.envres.2019.109081

Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillan, A., Field, A., Baas, P., & Mackie, H. (2017). Systematic literature review of built environment effects on physical activity and active transport–an update and new findings on health equity. *International Journal of Behavioral Nutrition and Physical Activity*, *14*, 1-27. https://doi.org/10.1186/s12966-017-0613-9

Smith, M. G., Cordoza, M., & Basner, M. (2022). Environmental noise and effects on sleep: An update to the WHO systematic review and meta-analysis. *Environmental Health Perspectives*, *130*(7), 076001. https://doi.org/10.1289/EHP1019

Smith, T. O., Davies, L., De Medici, A., Hakim, A., Haddad, F., & Macgregor, A. (2016). Prevalence and profile of musculoskeletal injuries in ballet dancers: A systematic review and meta-analysis. *Physical Therapy in Sport*, *19*, 50-56. https://doi.org/10.1016/j.ptsp.2015.12.007

Stenfors, C. U., Stengård, J., Hanson, L. L. M., Kecklund, L. G., & Westerlund, H. (2023). Green sleep: Immediate residential greenspace and access to larger green areas are associated with better sleep quality, in a longitudinal population-based cohort. *Environmental Research*, *234*, 116085. https://doi.org/10.1016/j.envres.2023.116085

Sutil, D. V., Moreira, B. D. S., Canever, J. B., Cândido, L. M., Danielewicz, A. L., Lima-Costa, M. F., & Avelar, N. C. P. D. (2024). Association between self-perception of the neighborhood environment and sleep problems in older Brazilian adults: Findings from ELSI-Brazil. *Cadernos de Saúde Pública*, *40*, e00141623. https://doi.org/10.1590/0102-311XEN141623

Tang, M., Li, D., Liew, Z., Wei, F., Wang, J., Jin, M., Chen, K., & Ritz, B. (2020). The association of short-term effects of air pollution and sleep disorders among elderly residents in China. *Science of The Total Environment*, *708*, 134846. https://doi.org/10.1016/j.scitotenv.2019.134846

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BioMed Central Medical Research Methodology*, *8*, 1-10. https://doi.org/10.1186/1471-2288-8-45

Troxel, W. M., DeSantis, A., Richardson, A. S., Beckman, R., Ghosh-Dastidar, B., Nugroho, A., Hale, L., Buysse, B. j., Buman, M. P., & Dubowitz, T. (2018). Neighborhood disadvantage is associated with actigraphy-assessed sleep continuity and short sleep duration. *Sleep*, *41*(10), zsy140. https://doi.org/10.1093/sleep/zsy140

Tubbs, A. S., Dollish, H. K., Fernandez, F., & Grandner, M. A. (2019). The basics of sleep physiology and behavior. In M. A. Grandner (Ed.), *Sleep and health* (pp. 3-10). Academic Press.

Wang, H., Sun, J., Sun, M., Liu, N., & Wang, M. (2022a). Relationship of sleep duration with the risk of stroke incidence and stroke mortality: An updated systematic review and dose–response meta-analysis of prospective cohort studies. *Sleep Medicine*, *90*, 267-278. https://doi.org/10.1016/j.sleep.2021.11.001

Wang, S., Li, Z., Wang, X., Guo, S., Sun, Y., Li, G., Zhao, C., Yuan, W., Li, M., Li, X., & Ai, S. (2022b). Associations between sleep duration and cardiovascular diseases: A meta-review and meta-analysis of observational and Mendelian randomization studies. *Frontiers in Cardiovascular Medicine*, *9*, 930000. https://doi.org/10.3389/fcvm.2022.930000

World Health Organization (2010). *Noise.* World Health Organization. https://www.who.int/europe/news-room/fact-sheets/item/noise#:~:text=How%20many%20people%20are%20affected,dB(A)%20at%20night.

World Health Organization. (2016). *Urban green spaces and health*. World Health Organization. https://iris.who.int/handle/10665/345751

World Health Organization (2024). *Ambient (outdoor) air pollution.* World Health Organization. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

Xu, X., Lan, L., Sun, Y., & Lian, Z. (2023). The effect of noise exposure on sleep quality of urban residents: A comparative study in Shanghai, China. *Building Simulation*, *16*(4), 603-613. https://doi.org/10.1007/s12273-022-0972-2

Yu, H., An, R., & Andrade, F. (2017). Ambient fine particulate matter air pollution and physical activity: A longitudinal study of university retirees in Beijing,

China. *American Journal of Health Behavior*, *41*(4), 401-410. https://doi.org/10.5993/AJHB.41.4.4

Yu, H., Chen, P., Paige Gordon, S., Yu, M., & Wang, Y. (2019). The association between air pollution and sleep duration: A cohort study of freshmen at a university in Beijing, China. *International Journal of Environmental Research and Public Health*, *16*(18), 3362. https://doi.org/10.3390/ijerph16183362

Zhang, J., He, M., Wang, X., Jiang, H., Huang, J., & Liang, S. (2024). Association of sleep duration and risk of mental disorder: A systematic review and meta-analysis. *Sleep and Breathing*, *28*(1), 261-280. https://doi.org/10.1007/s11325-023-02905-1

Zhao, H., Ma, Y., Liu, N., & Long, Y. (2025). A systematic review of the association between neighborhood physical disorder and individual health. *Discover Cities*, *2*(1), 11. https://doi.org/10.1007/s44327-025-00050-w

Zhao, Y., Zhang, S., Guo, L., Xiao, M., Han, Z., Yang, Y., Wang, B., Li, P. (2023). Association between air pollutants and the risk of sleep disorders: A systematic review and meta-analysis. *Aerosol and Air Quality Research*, *23*, 230197. https://doi.org/10.4209/aaqr.230197

Zhou, P., Ma, J., Li, X., Zhao, Y., Yu, K., Su, R., Zhou, R., Wang, H., & Wang, G. (2023). The long-term and short-term effects of ambient air pollutants on sleep characteristics in the Chinese population: Big data analysis from real world by sleep records of consumer wearable devices. *Biomed Central Medicine*, *21*(1), 83. https://doi.org/10.1186/s12916-023-02801-1

Appendix A

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	
	23b	Discuss any limitations of the evidence included in the review.	
	23c	Discuss any limitations of the review processes used.	
	23d	Discuss implications of the results for practice, policy, and future research.	
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

Appendix B

CASP Cohort Quality Appraisal Tool

CASP Checklist:
For Descriptive/Cross-Sectional Studies

Reviewer Name:	
Paper Title:	
Author:	
Web Link:	
Appraisal Date:	

During critical appraisal, never make assumptions about what the researchers have done. If it is not possible to tell, use the "Can't tell" response box. If you can't tell, at best it means the researchers have not been explicit or transparent, but at worst it could mean the researchers have not undertaken a particular task or process. Once you've finished the critical appraisal, if there are a large number of "Can't tell" responses, consider whether the findings of the study are trustworthy and interpret the results with caution.

Section A: Are the results valid?	
1. Did the study address a clearly focused issue?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *A question can be 'focused' in terms of* • *the population studied* • *the risk factors studied* • *is it clear whether the study tried to detect a beneficial or harmful effect* • *the outcomes considered*	
2. Did the authors use an appropriate method to answer their question?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Is a descriptive/cross-sectional study an appropriate way of answering the question* • *did it address the study question*	
3. Were the subjects recruited in an acceptable way?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *We are looking for selection bias which might compromise the generalisability of the findings:* • *Was the sample representative of a defined population* • *Was everybody included who should have been included*	
4. Were the measures accurately measured to reduce bias?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *Look for measurement or classification bias:* • *did they use subjective or objective measurements* • *do the measurements truly reflect what you want them to (have they been validated)*	
5. Were the data collected in a way that addressed the research issue?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *if the setting for data collection was justified* • *if it is clear how data were collected (e.g., interview, questionnaire, chart review)* • *if the researcher has justified the methods chosen* • *if the researcher has made the methods explicit (e.g. for interview method, is there an indication of how interviews were conducted?)*	
6. Did the study have enough participants to minimise the play of chance?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if the result is precise enough to make a decision* • *if there is a power calculation. This will estimate how many subjects are needed to produce a reliable estimate of the measure(s) of interest.*	
7. How are the results presented and what is the main result?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if, for example, the results are presented as a proportion of people experiencing an outcome, such as risks, or as a measurement, such as mean or median differences, or as survival curves and hazards* • *how large this size of result is and how meaningful it is* • *how you would sum up the bottom-line result of the trial in one sentence*	
8. Was the data analysis sufficiently rigorous?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if there is an in-depth description of the analysis process* • *if sufficient data are presented to support the findings*	
9. Is there a clear statement of findings?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *if the findings are explicit* • *if there is adequate discussion of the evidence both for and against the researchers' arguments* • *if the researchers have discussed the credibility of their findings* • *if the findings are discussed in relation to the original research questions*	
10. Can the results be applied to the local population?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *the subjects covered in the study could be sufficiently different from your population to cause concern.* • *your local setting is likely to differ much from that of the study*

11. How valuable is the research?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *one descriptive/cross-sectional study rarely provides sufficiently robust evidence to recommend changes to clinical practice or within health policy decision making* • *if the researcher discusses the contribution the study makes to existing knowledge (e.g., do they consider the findings in relation to current practice or policy, or relevant research-based literature?)* • *if the researchers have discussed whether or how the findings can be transferred to other populations*

APPRAISAL SUMMARY: *List key points from your critical appraisal that need to be considered when assessing the validity of the results and their usefulness in decision-making.*		
Positive/Methodologically sound	**Negative/Relatively poor methodology**	**Unknowns**

Appendix C

JBI Quasi-Experimental Quality Appraisal Tool

JBI CRITICAL APPRAISAL CHECKLIST FOR QUASI-EXPERIMENTAL STUDIES

Reviewer_____Date_____

Author_____Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
1. Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	☐	☐	☐	☐
2. Were the participants included in any comparisons similar?	☐	☐	☐	☐
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	☐	☐	☐	☐
4. Was there a control group?	☐	☐	☐	☐
5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?	☐	☐	☐	☐
6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	☐	☐	☐	☐
7. Were the outcomes of participants included in any comparisons measured in the same way?	☐	☐	☐	☐
8. Were outcomes measured in a reliable way?	☐	☐	☐	☐
9. Was appropriate statistical analysis used?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

Appendix D

CASP Cohort Quality Assessment

Study	Q1	Q2	Q3	Q4	Q5a	Q5b	Q6a	Q6b	Q7	Q8	Q9	Q10	Q11	Q12	Y	N/C	Overall
An & Yu (2018).	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	C	Y	C	12	2	High
Astell-Burt & Feng (2020)	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	13	1	High
Bozigar et al. (2023)	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	C	Y	C	10	4	High
Héritier et al. (2014)	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	13	1	High
Hu et al. (2024)	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	13	1	High
Kim et al. (2022)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	C	Y	C	12	2	High
Kim et al. (2023)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	C	Y	C	12	2	High
Li et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	C	Y	Y	12	2	High
Lin et al. (2023)	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	13	1	High
Liu et al. (2023b)	Y	Y	Y	N	Y	Y	C	Y	Y	Y	Y	Y	Y	Y	12	2	High
Martens et al. (2018)	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	13	1	High
Stenfors et al. (2023)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	14	0	High
Yu et al. (2017)	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	C	Y	C	11	3	High
Yu et al. (2019)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	C	Y	C	12	2	High

Note. Y = Yes; N = No; C = Can't tell; Y column = Yes counts; N/C column = No and Can't tell count; Overall = yes answers of <5=low, 6-8=moderate, and >8-10=high quality.

Appendix E

JBI Quasi-Experimental Quality Assessment

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Y	N/U	NA	Overall
Amundsen et al. (2013)	Y	Y	Y	Y	Y	Y	Y	U	Y	9	0	0	High
Barros et al. (2024)	Y	Y	Y	Y	Y	Y	Y	U	Y	8	1	0	High
Brink et al. (2023)	Y	NA	NA	N	Y	Y	Y	U	Y	5	2	2	High
Nilsson & Berglund (2006)	Y	Y	Y	Y	Y	Y	Y	U	Y	8	1	0	High
Schreckenberg et al. (2016)	Y	NA	NA	N	Y	Y	Y	U	Y	5	2	2	High
Öhrström (2004)	Y	Y	Y	Y	Y	Y	Y	U	Y	8	1	0	High
Xu et al. (2023)	Y	NA	NA	N	Y	Y	Y	U	Y	5	2	2	High

Note. Y = Yes; N = No; U = unclear; NA = not applicable; Y column = Yes counts; N/U column = No and Unclear; NA column = not applicable; Overall = yes answers of <4.5=low 4.5-6=moderate, and ≥6=high quality.

Appendix F

CASP Systematic Review Appraisal Tool

CASP Checklist:
For systematic reviews with meta-analysis of observational studies

Reviewer Name:	
Paper Title:	
Author:	
Web Link:	
Appraisal Date:	

During critical appraisal, never make assumptions about what the researchers have done. If it is not possible to tell, use the "Can't tell" response box. If you can't tell, at best it means the researchers have not been explicit or transparent, but at worst it could mean the researchers have not undertaken a particular task or process. Once you've finished the critical appraisal, if there are a large number of "Can't tell" responses, consider whether the findings of the study are trustworthy and interpret the results with caution.

Section A: Is the basic study design valid for a systematic review?	
1. Did the systematic review address a clearly formulated research question?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *Did the researchers state a research question and a null hypothesis?* *For a systematic review of observational studies, a research question can be 'formulated' in terms of the PECOT(S) framework:* • *Population* • *Exposure/Risk factor* • *Detection of a beneficial or harmful effect* • *Comparator/Controls* • *Outcome/s or Event/s* • *Time, e.g., length of time in which to detect outcomes or events, or time of exposure* • *Setting*	
2. Did the researchers search for appropriate study design(s) to answer the research question?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *If the research question is concerned with the identification of risk factors or exposures associated with a particular event or outcome, observational studies are appropriate study designs to address the research question in a systematic review, for example:* • *Cohort studies follow a group of people who share a common characteristic or exposure over time and compare them with another group who do not have that characteristic or exposure.* • *Case-control studies compare a group of people who have a specific outcome or condition (cases) with a group of people who do not have it (controls) and look for differences in their past exposures or risk factors.* • *Cross-sectional studies measure the prevalence of a characteristic, outcome, or exposure in a population at a single point in time or over a short period.*	
Notes to support interpretation of Section A, Questions 1 and 2: If you answered "No" to both these questions: • It is likely that the researchers did not clearly formulate the fundamental aspects of the research question, and the most appropriate way of answering it. If this is the case, it is likely other problems will arise during the conduct of the systematic review • Consider whether it would be useful to continue with the critical appraisal process	
Section B: Is the systematic review methodologically sound?	

3. Were all the relevant primary research studies likely to have been included in the systematic review? a) Searching for primary research studies	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Was the search strategy comprehensive and clearly reported?* • *Did the search include 1 or more of the major bibliographic databases, e.g., MEDLINE/PubMed, and Embase?* • *Did the researchers provide MESH terms for MEDLINE, or their equivalent for other databases?* • *Were relevant subject-specific bibliographic databases searched?* • *Did the search include non-English language studies?* • *Did the researchers undertake citation searching, including hand-searching of reference lists from primary research studies included in the systematic review?* • *Did the search include unpublished studies? For instance, did the search include registers of ongoing trials or preprint repositories?* • *Did the researchers consult experts in the field about potential primary research studies or ongoing trials that could be included?*	
b) Screening primary research studies from the search	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Did the researchers define appropriate eligibility or inclusion and exclusion criteria for the research question?* • *Did the researchers design and implement a robust process to screen the primary research studies? For instance, two researchers working independently, with a third independent researcher to resolve any disagreements.* • *Was screening based on title and abstract of primary research studies found during the search?* • *Did the researchers adhere to the eligibility criteria?*	
c) Selecting primary research studies to include in the systematic review	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Did the researchers design and implement a robust process to select the primary research studies according to the eligibility criteria? For instance, two researchers working independently, with a third independent researcher to resolve any disagreements.*	

• *Were decisions to include or exclude primary research studies based on full-text analysis?* • *Did the researchers adhere to the eligibility criteria?* • *Was the level of agreement between the researchers responsible for selecting the primary research studies calculated and reported? For instance, by calculating the kappa statistic of inter-rater reliability?*	
d) Summarising the search and its outputs	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *Did the researchers present a PRISMA-type flowchart, including the numbers of primary research studies that were:* • *Duplicates?* • *Screened out?* • *Excluded, with the reasons for exclusion?* • *Included in the systematic review?* • *Included in the meta-analysis (data may not have been complete in some of the primary research studies)?*	
4. Did the researchers assess the validity or methodological rigour of the primary research studies included in the systematic review?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: *Lack of methodological rigour in the individual primary research studies can affect the validity and interpretation of the findings of the systematic review with meta-analysis.* • *Did the researchers use a validated tool to assess the methodological rigour of the primary research studies included in the systematic review?* • *Was the tool appropriate to assess the type(s) of study design(s) included in the systematic review? For example, for case-control and cohort studies, the Newcastle-Ottawa Scale or the ROBINS-E tool.* • *Did the researchers present the findings from their quality assessment in sufficient detail, and interpret them accurately?*	
5. Did the researchers extract, and present information from the individual primary research studies appropriately and transparently? (a) Extraction of data	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *Did the researchers design and implement a robust process for the extraction of data from the individual primary research studies?* • *Did the researchers follow guidance on data extraction?* • *Did the researchers use a standardised form or software programme to record the data to ensure completeness and accuracy?* • *Did the researchers extract the relevant data for the study-level characteristics and the results of each primary research study?*	
(b) Presentation of data	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Did the researchers present the key characteristics of the individual primary research studies, e.g., in a table? For instance, the number of participants, the profile of participants (age, sex), the intervention, the comparator, the outcome/s evaluated, and the study timeframe.* • *Did the researchers present the results of the individual primary research studies in a Forest plot or combination of table and Forest plot? For instance, the effect size/s, the confidence-interval ranges, and the P values. NB: The Forest plot should also show the overall result from the meta-analysis*	
Notes to support the interpretation of Section B, Questions 3-5: If you answered "No" to these questions, it is likely that there is a lack of methodological rigour in the conduct of the systematic review, which means it is best to interpret the results with caution, and to assess how those aspects of poor methodology will have an impact on the results of the systematic review. • For *Question 3*, a "No" response indicates that this systematic review may have missed primary research studies that could have contributed to answering the research question; in a systematic review with meta-analysis, the results of any missing primary research studies could have altered the effect estimate for the systematic review. • For *Question 4*, a "No" response indicates that the researchers did not identify any systematic bias or confounding factors in the primary research studies that could have affected the results of the systematic review; in the absence of this information, it is not possible for you to assess in what ways the results of the systematic review could have been affected, and it is best to be cautious when interpreting the results. • For *Question 5*, a "No" response indicates that the researchers did not organise the data from the primary research studies in a coherent way such that it could analysed appropriately, and thereby reliable conclusions drawn from it. If you answered "No" to all three questions in Section B, consider whether it would be useful to continue with the critical appraisal process.	
Section C: Are the results of the systematic review trustworthy?	
6. Did the researchers analyse the pooled results of the individual primary research studies appropriately?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *Did the researchers undertake a sample-size estimation during the design and planning of the systematic review?* • *Did the number of participants whose outcomes were entered into the analysis meet that estimation, i.e., was the sample size sufficient to detect any effect on the outcomes of interest?* • *Did the researchers use an appropriate effect measure?* • *Did the researchers provide confidence-interval ranges for the effect estimates in the systematic review?* • *Did the researchers provide p values for the effect estimates in the systematic review?* • *Did the researchers provide a minimal important difference, that is the smallest possible difference in outcome that would be meaningful to people experiencing the exposure or risk factor?* • *Did the researchers assess the level of statistical heterogeneity (variability) among the primary research studies? For example, using the I^2 statistic.* • *Did the researchers use an appropriate model of meta-analysis for the level of heterogeneity among the primary research studies (a random-effects model if there was heterogeneity or a fixed-effects model if the primary research studies were all investigating the same underlying effect)?* • *Did the researchers perform any sensitivity analyses?* • *Did the researchers analyse the reasons for heterogeneity using subgroup analysis or meta-regression? For subgroup analysis, see Question 6.1, and for meta-regression see Question 6.2.* • *Did the researchers investigate the small-study-effect, and assess the potential for publication bias in the systematic review (e.g., using a funnel plot)?*	
6.1 Subgroup analysis	Yes ☐ No ☐ Can't Tell
CONSIDER: *Were the characteristics or effect modifiers for investigation:* • *Specified in the study protocol, with the direction of effect, and statistical tests to be used?* • *Clearly defined, with a rationale for selection?* • *Not closely related to other characteristics, i.e., differentiation is possible?* • *Analysed in relation to the primary outcome?* *If continuous data were allocated to categories, were the thresholds or cut-off points specified in the study protocol together with a rationale?* *If a large number of characteristics were investigated, or subgroup analyses conducted, did the researchers adjust for multiple testing?* *Was a test for interaction undertaken to determine whether any subgroup effects were statistically significant?* *Was the analysis of effect modification based on comparison within rather than between studies?*	
6.2 Meta-regression	Yes ☐ No ☐ Can't Tell

CONSIDER: *Were the characteristics or effect modifiers for investigation:* • *Specified in the study protocol, with the direction of effect?* • *Continuous data? If continuous data were allocated to categories, were the thresholds or cut-off points specified in the study protocol with a rationale for selection?* *If a large number of characteristics or effect modifiers were investigated, or meta-regression analyses performed, did the researchers adjust for multiple testing?* *Was a test for interaction undertaken to determine whether any effects were statistically significant?* *Was a random-effects model used for the meta-regression analyses?* *Was the analysis of effect modification based on comparison within rather than between studies?*	
7. Did the researchers report any limitations of the systematic review and, if so, do the limitations discussed cover all the issues you have identified during critical appraisal?	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *Did the researchers comment on the size of the sample in the meta-analysis and whether it was large enough to detect an effect of the exposure or risk factor if there was one?* • *Did the researchers consider the appropriateness of the effect measure or measures they used?* • *Did the researchers reflect on the precision of the results of the systematic review, i.e., the confidence-interval range? The smaller the range, the narrower the confidence intervals, meaning the result is more precise, and closer to the true effect size.* • *If relevant, did the researchers note whether the confidence-interval range included the "line of no effect" (0 for a difference, 1 for a ratio, where the null hypothesis holds true), or whether the lower limit of the confidence-interval range was close to the "line of no effect", and discuss the implications for the results of the meta-analysis?* • *If the results were statistically significant (i.e., they were less likely to be due to chance), did the researchers discuss whether the results would be important or meaningful for the outcomes experienced by individuals and/or populations using a minimal important difference specific to the research question?* • *Did the researchers consider whether relevant primary research studies could have been missed?* • *Did the researchers mention any systematic bias identified during the risk-of-bias/quality assessment of the primary research studies, and explain how it might have influenced the effect estimate in the meta-analysis?* • *Did the researchers mention any potential sources of confounding that could have influenced the effect estimate in the meta-analysis?* • *Did the researchers discuss the implications of any sensitivity analyses?* • *Did the researchers discuss the impact of the level of heterogeneity on the results of the meta-analysis?* • *Did the researchers investigate the reasons for any heterogeneity across the primary research studies and discuss the implications? For subgroup analysis, see Question 7.1, and for meta-regression, see Question 7.2.* • *Did the researchers discuss the effect of any publication bias on the results of the meta-analysis?*	
7.1 Subgroup analysis	☐ Yes ☐ No ☐ Can't Tell

CONSIDER: • *If characteristics or effect modifiers were not pre-specified, did the researchers address whether bias was introduced into the analysis?* • *Did the researchers reflect on whether the characteristics or effect modifiers selected were well-defined to ensure clarity about the effect being investigated?* • *If no rationale was given for the selection of specific characteristics or effect modifiers, or the rationale was not supported by evidence or a plausible argument of meaningfulness, did the researchers discuss whether this affected the validity or relevance of the subgroup analysis?* • *If characteristics or effect modifiers were closely related to other characteristics, did the researchers mention the potential for confounding?* • *Did the researchers outline whether the sample sizes in any subgroup analyses were sufficient to detect an effect of the exposure or risk factor on the primary outcome?* • *If continuous data were allocated to categories, did the researchers address whether the thresholds or cut-off points could have introduced bias into the subgroup analysis or were not meaningful either clinically or in terms of public and population health?* • *If more than three characteristics or effect modifiers were investigated or subgroup analyses performed, did the researchers adjust for multiple testing and consider the potential to generate Type I errors?* • *Did the researchers explain the results of any tests for interaction, and whether they were statistically significant?* • *Did the researchers discuss the implications of whether the results of tests for interaction were quantitative or qualitative?* • *If the analysis of effect modification was based on a comparison between studies, did the researchers reflect on whether the number of studies in the smallest subgroups was large enough for the results to be credible?*	
7.2 Meta-regression	☐ Yes ☐ No ☐ Can't Tell
CONSIDER: • *If characteristics or effect modifiers were not pre-specified, did the researchers address whether bias was introduced into the analysis?* • *If continuous data were allocated into categories, did the researchers address whether any thresholds or cut-off points for categorisation were arbitrary and could have introduced bias into the meta-regression or whether they were not meaningful clinically and/or in terms of public and population health?* • *If more than three characteristics or effect modifiers were investigated, or meta-regression analyses performed, did the researchers adjust for multiple testing and consider the potential to generate Type I errors?* • *Did the researchers discuss the implications of any tests for interaction and whether they were statistically significant?*	

- *If a random-effects model was not used to account for residual heterogeneity and/or mixed effects, which would have allowed for both within-study and between-study variation, did the researchers outline the implications for the results?*
- *If the analysis of effect modification was based on a between-study comparison, did the researchers reflect on whether the number of primary research studies in the meta-regression was sufficient for the results to be credible?*

8. Would the benefits of acting upon the results outweigh any potential disadvantages, harms and/or additional demand for resources associated with acting on the results?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER:

- *Are you clear about the likely benefits of acting upon the results bearing in mind the potential impacts of any study limitations?*
- *Did the researchers identify any potential disadvantages, unwanted outcomes, or negative impacts of acting on the results of the systematic review?*
- *If so, did the researchers assess any benefits against the disadvantages, unwanted outcomes, or negative impacts, and discuss the overall balance between benefit and harm?*
- *Did the researchers report any information on the potential demand for resources (e.g., cost, workforce, time, skills levels/skill mix, training needs, data collection and analysis, IT requirements) that might be associated with acting on the results of the systematic review?*

- **Notes to support interpretation of Section C, Questions 6, 7 & 8:** If you answered "No" to these questions, it is likely that the researchers did not analyse and interpret the information from the primary research studies appropriately, nor did they discuss the limitations of the systematic review as fully as possible so it is not possible for you to assess the trustworthiness (validity and credibility) of the results of the systematic review. Finally, if there is no information on the likely resource demands of intervention, it is not possible for you to judge whether you have the resource capacity to act upon the results.

If you answered "No" to all three questions in Section C, consider whether it would be useful to continue with the critical appraisal process.

Section D: Are the results of the systematic review relevant locally?

9. Can the results of the systematic review be applied to your local population/in your local setting or context?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER:

- *Are there differences between your local population and the participants in the primary research studies in the systematic review that would influence whether you would act upon the results?*
- *Are there differences between your local setting and the settings or contexts in the primary research studies in the systematic review that would influence whether you would act upon the results?*
- *Are there any outcomes or other factors that the researchers could have studied that would have been useful to you bearing in mind the needs of your local population and/or setting?*

Notes to support interpretation of Section D, Question 9:

- If you answered "No" to this question, it is not necessary to answer Question 10 because, irrespective of a systematic review's methodological rigour, the results are not applicable to the individuals or populations for whom you are responsible.
- If you answered "Yes" to Question 9, answer Question 10

Section E: Will the implementation of the results represent greater value for your service users or population?

10. If actioned, would the findings from the systematic review represent greater or additional value for the individuals or populations for whom you are responsible?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER:
Value equals the Outcome/s (Benefit minus Harm) divided by the Resources required for implementation.

- *What resources would be needed to take action on the findings of the systematic review? Take account of various types of resource, not only costs, but also time, skills mix, skills development or training needs, IT requirements, and other material resources.*
- *If necessary, are you able to disinvest resources from other activities to be able to re-invest in actioning the findings from the systematic review?*

Notes to support interpretation of Section E, Question 10:

- *If you answered "No" to this question, it is likely that the findings of the systematic review will not confer greater or additional benefit or value on the individuals and/or populations for whom you are responsible, despite the systematic review's applicability to your local setting.*
- *If you answered "Yes" to the question, it is likely that the findings of the systematic review will confer greater or additional benefit or value on the individuals and/or populations for whom you are responsible, and you need to discuss with colleagues whether it would be appropriate to implement the findings in your local setting.*

What is your conclusion about the systematic review – can it be used to support evidence-based decision-making?	☐ Yes ☐ No ☐ Can't Tell

CONSIDER:

- *Would you use it to change practice or to recommend changes to care policy and procedures in your organisation?*
- *Could you judiciously take action on the information about the exposure or risk factor without delay?*

CASP General SR Checklist: Collation of critical appraisal responses

Yes	Checklist question	Can't tell	No
	A. Is the basic study design valid for a systematic review?		
	1. Did the systematic review address a clearly formulated research question?		
	2. Did the researchers search for appropriate study designs to answer the research question?		
	B. Is the systematic review methodologically sound?		
	3. Were all relevant primary research studies likely to have been included in the systematic review?		
	4. Did the researchers assess the validity or methodological rigour of the primary research studies included in the systematic review?		
	5. Did the researchers extract, and present information on the individual primary research studies appropriately and transparently?		
	C. Are the results of the systematic review trustworthy?		
	6. Did the researchers analyse the results of the individual primary research studies appropriately?		
	7. Did the researchers report any limitations of the systematic review and, if so, do the limitations discussed cover all the issues in your critical appraisal?		
	8. Would the benefits of acting upon the results outweigh any potential disadvantages, harms and/or additional demand for resources associated with acting on the results?		
	D. Are the results of the systematic review relevant locally?		
	9. Can the results of the systematic review be applied to your local population/in your local setting or context?		
	E. Will the implementation of the results represent greater value for your service users or population?		
	10. If actioned, would the findings from the systematic review represent greater or additional value for the individuals or populations for whom you are responsible?		

APPRAISAL SUMMARY: *List key points from your critical appraisal that need to be considered when assessing the validity of the results and their usefulness in decision-making.*		
Positive/Methodologically sound	**Negative/Relatively poor methodology**	**Unknowns**

Section Two: Empirical Study

Social Determinants of Mental Health and Distress as Concomitants of Sleep Disturbance: A Structural Equation Modelling Approach

Abstract

Objectives: Examining the association between sleep disturbance, mental health (depression, anxiety, psychotic experiences), and social determinants of mental health at different levels of Bronfenbrenner's framework (microsystem, mesosystem, exosystem, and macrosystem).

Design and Method: A cross-sectional design (n = 2513) using the COVID-19 Psychological Research Consortium UK wave 5 survey data, which was analysed using structural equation modelling.

Results: Model fit indices were excellent (Comparative fit index = 0.950; Tucker-Lewis Index = 0.956; square error of approximation = 0.050; standardized root mean square residual = 0.078). Significant direct effects were found between sleep disturbance and material hardship (β = 0.44, $p < .001$; exosystem), being female (β = 0.06, $p = .005$), having a minority sexual orientation (β = 0.06, $p = .011$), socioeconomic stability (β = 0.07, $p = .038$; macrosystem), increased age (β = -0.11, $p < .001$), and support system (β = -0.11, $p < .001$; microsystem and mesosystem). However, declared religion (β = 0.03, $p = .137$) and ethnicity (β = 0.01, $p = .699$) were not found to be significantly associated with sleep. The same findings were observed for mental health, except for the direction of socioeconomic stability. Sleep disturbance was found to mediate the relationships between mental health and the social determinants.

Conclusion: This highlighted how social determinants acted as protective or risk factors for sleep disturbance, in addition to sleep mediating the relationships between these determinants and mental health. A public health approach could address this. Future research ought to examine these outcomes.

Keywords: sleep, mental health, social determinants, structural equation modelling, adults.

Practitioner Points

- Addressing wider socioecological factors through a preventative public health approach in collaboration with wider stakeholders.
- Implementing interventions that could improve infrastructure for strategic community-based support, cost of living and structural inequalities.
- Advocating for policy change through social reforms and redistribution of resources.

Introduction

Sleep disturbance is characterised by difficulties with initiating and maintaining sleep, daytime sleepiness, inconsistent sleep-wake cycles and unusual sleep behaviours (Cormier, 1990). Around 25% of people globally have reported dissatisfied sleep, and 6-10% have experienced insomnia symptoms (Morin & Benca, 2012). In turn, this could have adverse effects on daytime functioning (Altena & Ellis, 2021) and mental health (Cox & Olatunji, 2016). In parallel, sleep-related productivity loss was estimated at £30bn annually in the UK (Hafner et al., 2017), which highlighted individual and economic consequences of sleep disturbance.

Sleep disturbance has been attributed to a range of biological (e.g., España & Scammell, 2011) and psychological factors (e.g., Jansson-Fröjmark & Lindblom, 2008). However, solely focusing on these factors could limit the understanding of the multifaceted components that impact sleep and subsequently mental health, which could prevent addressing differences in sleep and result in suboptimal interventions and outcomes. Social determinants of mental health could offer insight into sleep through a shared context, which could account for both protective and risk factors in relation to individual, social, and societal factors (Sturgeon, 2006). These determinants have been proposed to reflect economic, social and environmental influences across the life span, such as material conditions, socioeconomic factors, social support, and systemic and structural inequalities, which could interact with individual characteristics (World Health Organization, 2014). Indeed, mental health difficulties, such as depression, anxiety, and psychotic experiences, which encompasses a broad range of clinical and subclinical symptoms prevalent in the general population (McGrath et al., 2016; Zhang et al., 2023; Zhong et al., 2024), have been found to be impacted by demographic characteristics (Lund et al., 2018; McManus et al., 2016; Post & Veling, 2021), economic factors (Lund et al., 2018; McManus et al., 2016), material hardship

(Arenas et al., 2019; Laaksonen et al., 2007), socioeconomic status (SES; Dougall et al., 2024), and social and cultural characteristics (Lund et al., 2018).

Research has similarly reported a strong association between poor sleep and social determinants of mental health. Specifically, material hardship, including food insecurity (Mazloomi et al., 2023) and difficulties with paying bills (Child et al., 2021), has been linked with poorer sleep. Furthermore, socioeconomic parameters, including lower income, education, and employment have similarly been found to be associated with worse sleep (Sosso et al., 2021). In contrast, having a strong support system (Kent de Grey et al., 2018), including strong neighbourhood social cohesion (Johnson et al., 2017) and being married compared to single (Hale, 2005), has been linked to better sleep. A potential mechanism behind this could have been that poor economic situation (Sinclair et al., 2024), material hardship (Pourmotabbed et al., 2020) and lack of social support (Cohen & Wills 1985) has been associated with stress, which could trigger the release of cortisol (Smith & Vale, 2006) and arousal that compromises sleep (Espie, 2002).

In terms of sociodemographic characteristics, these could buffer or amplify the influence from social determinants (World Health Organization, 2014). Specifically, being female (Zeng et al., 2020), increased age (Calem et al., 2012), belonging to a global majority group (Billings et al., 2021; Groeger & Hepsomali, 2023) or having a minority sexual orientation (Butler et al., 2020) have been associated with reduced sleep. Furthermore, similar outcomes have been reported for caregiving responsibilities (Byun et al., 2016) and having non-religious beliefs (Ellison et al., 2011; Krause & Ironson, 2017).

Whilst some papers examined social determinants in isolation, a few studies have assessed a combination of factors. A study by Grandner et al. (2015) with a US sample found that insufficient sleep was associated with being Black/African American, female, unmarried

and lower age. Moreover, socioeconomic factors, including lower income and education, unemployment and not having health insurance, and poorer physical and mental health, showed similar outcomes. A related study by Wu et al. (2025) found that Chinese women with a minority sexual orientation had worse sleep compared to cisgendered heterosexual women. Using structural equation modelling (SEM) they also observed that the women with a minority sexual orientation had lower social support, which reduced social and environmental quality of life that subsequently worsened sleep. However, these papers did not draw on the guidance of a theoretical framework.

Emerging evidence has similarly suggested that sleep disturbance play an important role in the development of poor mental health (Li et al., 2016; Cox & Olatunji, 2016; Pigeon et al., 2017). Sleep disturbance has not only been found to predict mental health (Baglioni et al., 2011; Hertenstein et al., 2019; Reeve et al., 2015), yet also mediate the relationship between poor mental health and financial strain (Chai & Lu, 2025), SES (McGuffog et al., 2023; Moore et al., 2002), neighbourhood quality (Hale et al., 2013) and social support (Gu et al., 2024). A possible explanation for this could have been that sleep disturbance has been found to amplify amygdala reactivity and reduce connectivity with the medial-prefrontal cortex (Yoo et al., 2007), which has been proposed to contribute to emotional dysregulation and thus mental health difficulties (Walker & van Der Helm, 2009).

In order to fully understand and address the complex interplay between sleep and social determinants of mental health, Bronfenbrenner's systems theory (1977) could offer a structural theoretical insight into contextual systems in relation to sleep. This framework highlighted the influence from the surrounding environment, broader social context, and their interactions with each other, which encompasses four systems; microsystem refers to the immediate contacts with the environment (e.g., family and neighbourhood); mesosystem relates to connections between immediate point of contacts (e.g., between family and

neighbours); exosystem takes into account the interaction between formal and informal structures (e.g., between family and community resources); and the macrosystem focuses on cultural elements (e.g., customs, laws and regulations; Bronfenbrenner, 1977). Correspondingly, this multivariable and multileveled approach could consider the influence of several factors at different levels that might contribute to sleep disturbance. Subsequently, this holistic approach could highlight how sleep might be shaped by broader contextual environmental and social experiences rather than choices, which could recognise systemic issues.

Bronfenbrenner's model has been applied for various contexts in relation to mental health, which provided recommendations for interventions and policies at the different levels. Specifically, the framework has been used to align social determinants of mental health with the United Nations Sustainable Development Goals (Lund et al., 2018), to understand mental health for men (Early & Devine, 2024), exploring mental health services for older adults in rural areas (Sanders et al., 2008) and counselling strategies for immigrant women (Yakushko & Chronister, 2005). A few papers have also drawn on Bronfenbrenner's model in relation to sleep. A review paper by Grandner et al. (2010) describe potential pathways between sleep and mortality, through impacts on physical health, across the different levels, yet they did not empirically test the model. Another paper by Li (2024) referenced the framework to position peer support as a micro-level influence on university student's sleep, however, the full model was not applied. Furthermore, a mixed-method study by McGuire et al. (2024) used the different levels to inform an interview schedule related to sleep and to code the answers, yet it was unclear how the result of room environment, sleep partner, and educational stress mapped onto the levels.

Although the associations between sleep disturbance and social determinants of mental health have been recognised, these have mainly been assessed in isolation or without a

theoretical framework. Moreover, while some papers have referenced Bronfenbrenner's model in relation to sleep, this was used conceptually or descriptively without multilevel interpretation. Thus, the influence of social determinants of mental health at the different levels of Bronfenbrenner's model on sleep, in addition to the role of sleep connecting these factors to mental health, has not been fully understood. Examining this could add to the research base by providing insight to wider relationships with a theoretical structure.

Research Aims

This UK adult population-based study's primary aim was to explore associations between sleep, mental health (depression, anxiety, psychotic experiences) and social determinants of mental health, at different levels of Bronfenbrenner's framework (microsystem, mesosystem, exosystem, and macrosystem) using SEM. The secondary aim was to test how well the proposed model fit the data by assessing underlying constructs and relationships between variables. In turn, this could provide insight to the multifaceted nature of sleep, highlight preventable differences and provide recommendations for interventions and policies.

Method

Design

The study implemented a cross-sectional design and used the COVID-19 Psychological Research Consortium UK wave 5 survey data (C19PRC-UKW5; McBride et al., 2022a) conducted between March to April 2021.

Ethical Approval

The C19PRC-UKW5 (McBride et al., 2022a) project received ethical approval by the University of Sheffield (033759). The present study was registered using a self-assessment

pro-forma with the University of Sheffield, which was approved by the University Research Ethics Committee (057562; Appendix A). The study was pre-registered on Open Science Framework (OSF; osf.oi/ry83n).

Participants

N = 2520 completed the C19PRC-UKW5 survey, and the inclusion criteria included 18 years or older, and having the ability to read and write in English. Prior to the C19PRC-UKW5, four previous waves had been carried out and the same participants who were part of the initial data collection were invited to participate in each subsequent wave (McBride et al., 2022a). At baseline, quota-based non-probability sampling was used to gather representative data. For each wave, attrition was addressed by replenishing participants to fill gaps in quotas for age, gender, and income, in addition, post-survey weighting ensured that the sample was representative of the UK population.

Once the C19PRC-UKW5 fieldwork started on 22nd March 2021, all the participants from the COVID-19 Psychological Research Consortium UK wave 4 survey (C19PRC-UKW4; McBride et al., 2022b) were re-contacted (24th March to 20th April 2021; n = 3867) via SMS, email or in-app notifications. The recontact rate was n = 2484, and n = 107 were screened out due to quality control checks, leaving n = 2377 with a 61.5% retention rate. Attrition was predicted by lower household income, having children, and mental health difficulties. This was followed by re-contacting n = 1082 participants, between 8th-20th April 2021, who had completed any previous wave prior to the C19PRC-UKW4 survey. The recontact rate was n = 173, where n = 30 were screened out due to quality control checks, leaving n = 143, with a retention rate of 13.2%.

Power Analysis

Monte Carlo simulations were completed to estimate statistical power for the SEM

framework (Wang & Rhemtulla, 2021) using RStudio version 4.4.3 and lavaan syntax (Rosseel, 2012). The framework included 54 indicators, five latent variables and 17 regression paths with a total of 73 parameters, where the effect size for the regression coefficient was set to 0.3, representing moderate effects (Cohen, 1988). Statistical power was set at 0.80, and simulations were run for sample sizes from 500-5000 with increments of 50, with 1000 replications for each.

The model-level power was examined by fit indices meeting their corresponding threshold, including Comparative fit index (CFI) ≥ 95 = excellent, Tucker-Lewis Index (TLI) ≥ 95 = excellent, standardized root mean square residual (SRMR) < 0.08 = good, and square error of approximation (RMSEA) ≤ 0.05 = good (Hu & Bentler, 1999). Whilst the parameter-level power assessed the proportion of factor loadings and paths that were statistically significance at $p > 0.05$. This showed that at n = 600, the model-level (0.87) and parameter-level (0.94) power exceeded 0.80.

Patient and Public Involvement

Patient and public involvement (PPI) was not implemented during the C19PRC-UKW5 study (McBride et al., 2022a) nor in the present study. PPI is commonly employed during the initial stages of project development, involving reviewing data collection tools, participant recruitment, consent forms and participant information sheets (Brett et al., 2014; Tomlinson et al., 2019). In turn, as secondary data analysis was carried out this did not present apparent ways to involve PPI (Morris et al., 2020).

Procedure

The C19PRC-UKW5 survey (McBride et al., 2022a) aimed to examine the prevalence of mental health and sleep difficulties, and to assess sociodemographic characteristics and

experiences from the pandemic within the sample. However, as ethnicity was not collated during this wave, the data for this was taken from the C19PRC-UKW4 survey.

Before going live, the survey was piloted on 22nd March 2021 on a new general population (n = 50), who were excluded from the final sample. This allowed to calculate the median time it took to complete the survey, 19.34 minutes, and address any coding errors. After the launch the median completion time was 31.28 minutes.

On 24th March 2021 the online survey went live, and it was supported by the platform Qualtrics. Participants were provided with a participant information sheet (Appendix B) and asked to complete informed electronic consent prior to completing the survey (Appendix C). They were informed of their right to withdraw at any time and that their data would be treated with confidence and no identifiable information was kept. Furthermore, the participants provided consent for their data being used for secondary analysis and that geolocational data was collected through their computer's IP address, which recorded their residential postcode stem. This was used to examine how many people had become poor due to COVID-19 in their area. After this had been collated the geolocational data and IP addresses were removed. The data is openly accessible for research purposes via OSF.

Measures

Sleep Disorders Symptom Checklist-17

The 17-items on the Sleep Disorders Symptom Checklist-17 (SDS-CL-17) assesses a range of sleep disturbances, including insomnia, circadian rhythm, narcolepsy, obstructive sleep apnoea, restless leg syndrome, and parasomnia, over the past year (Klingman et al., 2017; Appendix D). The frequency of symptoms and experiences (e.g., "*It takes me 30 minutes or more to fall asleep*") are rated on a 5-point Likert scale (0 "Never" to 4 "Frequently, more than 3 times per week"). A total score range between 0-68, with a higher

score indicating more severe sleep difficulties. The measure has been observed to have good criterion validity (sensitivity 0.70-0.79 and specificity 0.64-0.80; Klingman et al., 2017) and good internal reliability (Cronbach alpha 0.89; Savarimuthu & Subramanian; 2022).

Patient Health Questionnaire-9

The Patient Health Questionnaire-9 (PHQ-9) includes nine-items evaluating frequency and severity of depressive symptoms (e.g., "*Feeling down, depressed, or hopeless*") on a four-point Likert scale (0 "Not at all" to 3 "Nearly every day") over the past two weeks (Kroenke et al., 2001; Appendix E). The total score range between 0-27, and a higher score indicate greater depressive symptoms. The PHQ-9 has been shown to have good internal reliability (Cronbach alpha 0.89) and criterion validity (sensitivity 0.88 and specificity 0.88; Kroenke et al., 2001).

Generalized Anxiety Disorder-7

The seven-items on the Generalized Anxiety Disorder-7 (GAD-7) assesses experiences of anxiety (e.g., "*Feeling nervous, anxious or on edge"*) over the last two weeks (Spitzer et al., 2006; Appendix F). Each item is scored on a four-point Likert scale (0 "Not at all" to 3 "Nearly every day") with a total score ranging between 0-21, where a higher score represents greater anxiety. The GAD-7 has been shown to demonstrate excellent internal reliability (Cronbach alpha 0.92), and high criterion validity (sensitivity 0.89 and specificity 0.82; Spitzer et al., 2006).

Psychosis Screening Questionnaire

The Psychosis Screening Questionnaire (PSQ) examines psychotic experiences including presence of hallucinations, strange experiences, paranoid ideation, thought-interference, and hypomania with a total of 17-items, where a higher score indicates greater severity (Bebbington & Nayani, 1995; Appendix G).

Modifications had been made in the C19PRC-UKW5 study. For each symptom, a lifetime endorsement was assessed first (e.g. "*Have there been times when you heard or saw things that other people couldn't?*"; "Yes", "No'', "Unsure''), which had to be recognised before asking if these symptoms had been present in the past year ("*Did this happen in the last year?*"; "Yes'', "No'') and this was followed by a subsidiary question(s) corroborating the first item (e.g. "*Did you at any time hear voices saying quite a few words or sentences when there was no one around that might account for it?*"; "Yes'', "No'', "Unsure''). Additionally, one of the subsidiary questions for hypomania was reversed-coded as "No" indicated presence of symptoms and "Yes/Unsure" suggested a logical explanation. The criterion validity for the PSQ has been reported to be excellent (sensitivity 0.89 and specificity 0.82; Bebbington & Nayani, 1995).

Social Determinants of Mental Health

Sociodemographic Characteristics. Sociodemographic details were collected (Appendix H) including; age (18-24; 25-34; 35-44; 45-54; 55-64; 65 years and over); gender (male; female; transgender; prefer not to say; other); sexual orientation (straight / heterosexual; gay / lesbian / homosexual; bisexual; other; prefer not to say); ethnicity (Afro-Caribbean; African; Arab; Bangladeshi; Chinese; Indian; Other Asian; Other ethnic group; Pakistani; White British/Irish; White non-British/Irish); and declared religion (Atheist; Agnostic; Buddhist; Catholic; Hindu; Jewish; Protestant; Shia; Sikh; Sunni; Other).

Other factors gathered included relationship status (civil partnership; married; cohabiting; in a committed relationship but not living together; single and never been in a committed relationship; single but previously been in a committed relationship) and type of secondary school the participant had attended (private boarding school; private day school; state grammar school; state comprehensive school; home-schooled; did not attend secondary

school; other) with one item each. Parental status (no children; child/children under 18 years of age living in the household; child/children under 18 years of age living elsewhere; child/children aged 18 years or over age living in the household; child/children aged 18 years or over living elsewhere; someone else's child/children under 18 years of age living in the household) was also assessed with one item, yet with multiple choices.

Neighbourhood Characteristics. Neighbourhood belonging and comfort was assessed with three-items from the UK Community Life Survey (e.g., "*How much do you feel you belong to your immediate neighbourhood*?'') on a 4-point Likert scale (1 "Not at all" to 4 "Very much''; Cabinet Office, 2015; Appendix I).

Household finances. Items related to household finances (Appendix J), included yearly income in 2019 (£0-15,490; £15,491-£25,340; £25,341-£38,740; £38,741-£57,930; £57,931 or more), employment status (employed full-time; employed part-time; self-employed full-time; self-employed part-time; unemployed, but looking for work; unemployed, looking after family or home; unemployed; long-term sick or disability; on the furlough scheme; retired; full-time student) and receipt of benefits, excluding state pension and child benefits (''Yes'', "No''). Difficulties with paying bills was assessed with one item adapted from the Eurobarometer Survey ("*During the last month, would you say you found it difficult to pay your bills*?") on a 5-point Likert scale ("Very difficult" to "Not at all difficult"; Blanchflower & Clark, 2020).

Additionally, the eight-items on the Food Insecurity scale assessed food insecurity (e.g., "*You were worried you would run out of food because of a lack of money or other resources*?'') during the last year ("Yes'', "No''; Food and Agricultural Organisation, 2016). Whilst the MacArthur Scale of Subjective Social status assessed perceived rank of social status (1 worst off to 10 best off; Adler et al., 2000)

Data Analysis

SEM, employing Jeffreys's Amazing Statistics Program (JASP) 0.19.2, was used to assess the association between sleep disturbance, mental health (depression, anxiety, psychotic experiences) and the social determinants, where lavaan syntax was used (Rosseel, 2012). SEM includes a measurement component depicting the relationship between latent variables (underlying constructs) and their indicators (observed variables), and a structural component representing the relationship between endogenous and exogenous variables (MacCallum & Austin, 2000).

Weighted Least Squares with Mean and Variance adjustment (WLSMV) was selected for estimation purposes as majority of the data was binary or ordered and it is suitable for data that is not normally distributed (Li, 2016; Rhemtulla et al., 2012). Therefore, gender (female), ethnicity (global majority), relationship status (in a relationship), religion (declared), sexual orientation (minority), type of secondary school (private), parental status (having children or children living in the household), and employment (employed) were dummy coded to align with the requirement of WLSMV (Li, 2016; Rhemtulla et al., 2012). Gender was dummy coded for female and male only, as transgender (n = 4) and prefer not to say (n = 3) had very low cell sizes, which could reduce the power for detecting an effect (Walker & Smith, 2020). Correspondingly, as gender was an exogenous predictor and WLSMV employs listwise deletion for these variables with missing values (Rosseel et al., 2024), the sample being analysed was N = 2513. Additionally, due to the n = 149 missing data for ethnicity, imputation was performed using declared religion as the auxiliary variable. Moreover, parental status and type of secondary school attended, did not load onto any latent factor, nor did they predict any of the endogenous variables. Therefore, they were excluded from the model (CFI = 0.953; TLI = 0.961; RMSEA = 0.049; standardized root mean square residual SRMR = 0.078).

Based on conceptual and statistical consideration, the PSQ subscales were used instead of the individual items, which has been proposed to be acceptable in SEM (Vinnicombe et al., 2023). The conditional nature of the follow-up items in relation to the main item for each subscale, resulted in artificial correlations and estimation issues marked by factor loading above 1. Additionally, the hypomania subscale had a factor loading of 0.091, similar to the findings from Thungana et al. (2023), and it was therefore removed.

Model fit. The model fit was assessed with CFI ≥ 95 = excellent, TLI ≥ 95 = excellent, RMSEA ≤ 0.05 = good, SRMR; < 0.08 = good, and chi-square ($\chi 2$) $p < 0.05$ = acceptable; Hu & Bentler, 1999). However, $\chi 2$ could be sensitive to large sample sizes, manifested as a significant effect despite a well-fitting model (Bentler & Bonett, 1980). In contrast, other fit indices such as CFI and TLI have been considered more robust by correcting for sample size effects (Hu & Bentler, 1999).

Measurement component. Sleep, mental health, and social determinants of mental health, including material hardship, socioeconomic stability, and support system, which were defined based on theoretical and conceptual relevance (Baker, 2014; Beverly, 2001; Person, 1986), were considered the latent variables. In contrast, the indicators were the observed variables that measure the underlying latent constructs.

The dimensions which were used to evaluate the latent variables in the model were; the items on the SDS-CL-17 (Klingman et al., 2017) determined sleep disturbance; the PHQ-9 (Kroenke et al., 2001) and GAD-7 (Spitzer et al., 2006) items and the PSQ subscales (Bebbington & Nayani, 1995) reflected mental health; paying bills and the eight-items on the Food Insecurity scale (Food and Agricultural Organisation, 2016) determined material hardship; income, receipt of benefits, employment and social rank represented socioeconomic stability; and relationship status and the three-items from the UK Community Life Survey

(Cabinet Office, 2015), assessing neighbourhood belonging and comfort, determined support system. Confirmatory factor analysis was used to assess this through factor loading based on existing literature and theoretical meaningfulness, rather than through exploratory methods, to confirm and assess hypothesised constructs (Brown, 2015). These were assessed and interpreted using Hair et al. (2014) criteria; ≥ 0.8 high, ≥ 0.5 acceptable, and ≥ 0.3 lowest level of interpreting a construct.

Correlation amongst the residual variance for the exogenous variable's indicators, allowed to account for variance not captured by the latent constructs, which accurately represented the structure of the shared variance and enhanced the model's validity (Cole et al., 2007). These were used conservatively and accounted for 5% and 3% of possible indicator pairs for sleep disturbance and mental health respectively (MacCallum, 1995). Theoretical meaningfulness was considered, including items being worded similarly, having a shared concept, time-based framing, or reported by bed partner, in addition to examining Modification Indices (MacCallum, 1995; Kenny, 2011).

Structural component. The sequence in which the variables were included was determined by the literature (e.g., Baglioni et al., 2011; Chai & Lu, 2025; Gu et al., 2024; Hale et al., 2013; Hale, et al., 2020; Hertenstein et al., 2019; Lund et al., 2018; McGuffog et al., 2023; Moore et al., 2002; Reeve et al., 2015). Sleep and mental health were considered the endogenous variables, whilst material hardship, socioeconomic stability, and support system, in addition to age, being female, having a minority sexual orientation, belonging to the global majority, and declared religion were the exogenous variables.

Direct effects were assessed to examine how the exogenous variables predicted sleep disturbance and mental health. Additionally, indirect effects examined whether the relationship between mental health and the exogenous variables were mediated by sleep

disturbance (Baron & Kenny, 1986; Memon et al., 2018). The variables included in the regression paths acted as controls and adjusted for each other.

Statistical significance was indicated by $p > 0.05$ and β = standardized beta coefficient was used for the regression paths and factor loading. Outliers were assessed, yet the other assumptions in SEM including normal distribution, linearity, and time-sequence were not applicable due to the data being ordinal and cross-sectional (van Doorn et al., 2019).

Reflexivity

The author engaged in reflexivity through reflections in supervision and keeping a reflexive journal, to enhance rigor, transparency, and ethical integrity, as per Jamieson et al. (2023) recommendations for quantitative research.

The research questions stemmed from an interest in sleep, due to it being positioned at the intersection of mental health difficulties and systemic influences, interlinked by physiological, emotional and cognitive processes. Although this might have introduced potential biases, reflexivity was embedded at different stages. The participants provided consent for their data to be used in secondary analysis, indicating a level of agency. Additionally, considerations were given to how the data was coded, selection of indicators to latent variables, and variables to include in the regression and mediation based on theory. The conclusions were also interpreted based on factual results and the findings spoke to the wider research landscape, whilst also adding to it. In turn, reflexivity ensured that these steps were not influenced by personal biases shaped by the interest in sleep.

Results

The SEM examined relationships between sleep disturbance, mental health and social determinants of mental health. N = 2513 participants were included in the analysis with a mean age of 51 (female 49.44%; table 1).

Table 1

Demographics.

Characteristics	N = 2513 (M, SD)	%
Age	M = 51, SD = 15.07	
18-24	96	3.82
25-34	332	13.21
35-44	419	16.67
45-54	515	20.50
55-64	592	23.56
65+	559	22.24
Gender		
Male	1267	50.28
Female	1246	49.44
Sexual orientation		
Heterosexual	2286	90.97
Non-heterosexual	227	9.03
Ethnicity		
White	2375	94.51
Global majority	138	5.49
Declared religion		
No	925	36.81
Yes	1588	63.19
Relationship status		
Single	773	30.76
In a relationship	1749	69.24
Parent/children living in the household		
No	1054	41.94
Yes	1459	58.06
Secondary school		
Private	208	8.28

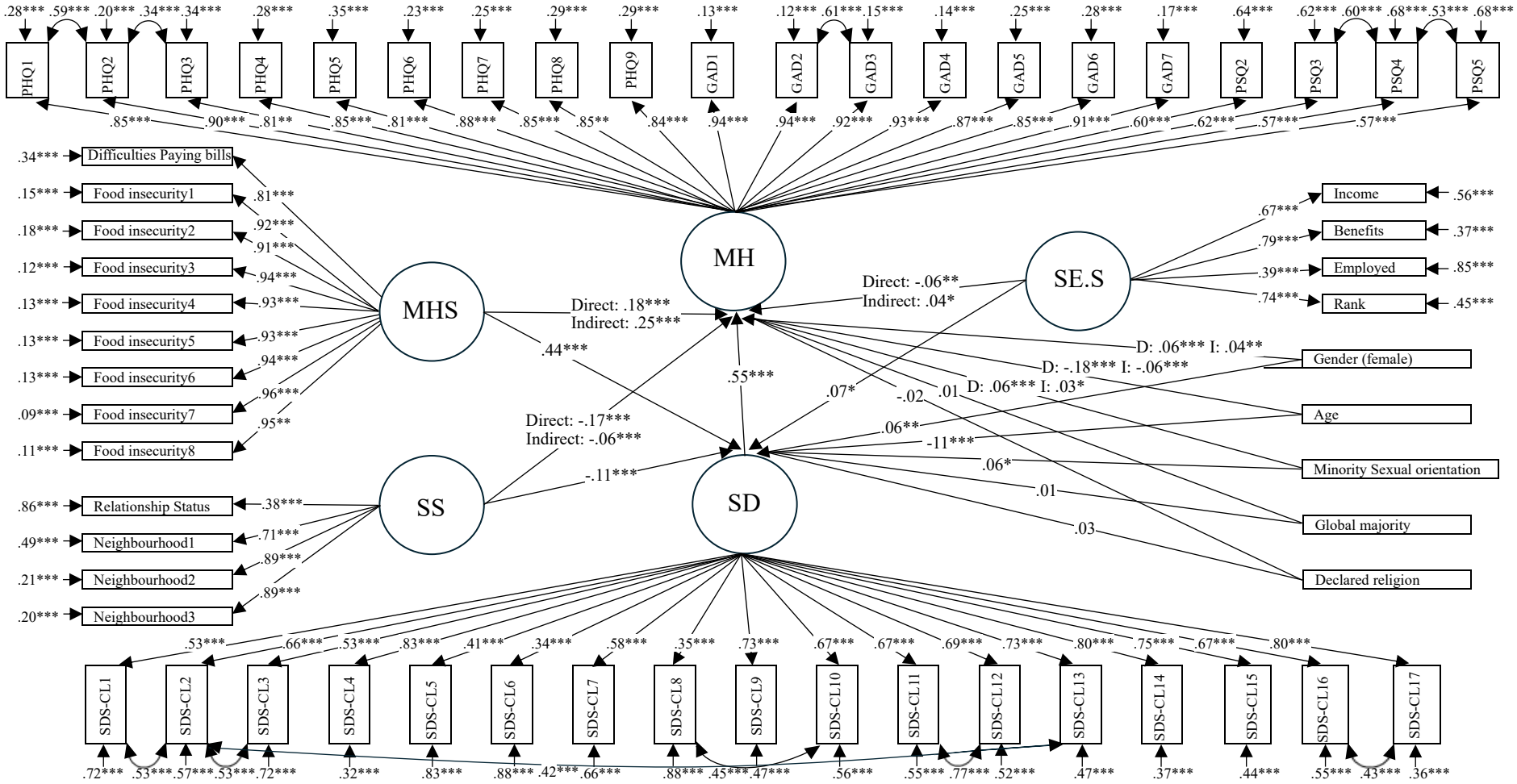
Non-private	2305	91.72
Household income		
£0-£15,490	478	19.02
£15,491-£25,340	464	18.46
£25,341-£38,740	561	22.33
£38,741-£57,930	517	20.57
£57,931 or more	493	19.62
Employment		
Employed	1473	58.62
Unemployed	1040	41.38
Unemployment due to the pandemic		
Yes	23	0.92
Receipt of benefits		
No	2050	81.58
Yes	463	18.42

Note. M = mean; SD = standard deviation.

Model fit: The fit indices suggested excellent fit (CFI = 0.950; TLI = 0.956; RMSEA = 0.050; SRMR = 0.078), yet $\chi 2 = 11798$, $p < .001$, was significant, which was expected due to the large sample size (figure 1).

Figure 1

Model.



Note. $p < .001$ = ***; $p < .01$ = **; $p < .05$ = *. D = Direct effect; Food insecurity = Food Insecurity scale; GAD = Generalized Anxiety Disorder; I = indirect; MH = mental health; MHS = Material hardship; Neighbourhood belonging and comfort = Community Life Survey; SE.S = socioeconomic stability; SD = sleep disturbance; SDS-CL = Sleep Disorders Symptom Checklist; SS = support system; PHQ = Patient Health Questionnaire; PSQ = Psychosis Screening Questionnaire subscales.

Measurement model: The observed indicators loaded significantly on to five latent constructs, including sleep disturbance, mental health, support system, material hardship and socioeconomic stability (Appendix K). Majority of the indicators had a standardised loading ranging from 0.53 to 0.96, which suggested good convergent validity.

In terms of factor loading, the strongest indicators of sleep were item four ($\beta = 0.83$, $p < .001$), fourteen ($\beta = 0.80$, $p < .001$) and seventeen ($\beta = 0.80$, $p < .001$) on the SDS-CL-17, representing insomnia, narcolepsy and parasomnia respectively, whilst the most powerful indicators of mental health were item one ($\beta = 0.94$, $p < .001$) and two ($\beta = 0.94$, $p < .001$) on the GAD7. Furthermore, the second ($\beta = 0.89$, $p < .001$) and third ($\beta = 0.89$, $p < .001$) items related to neighbourhood comfort on the Community Life Survey were the strongest indicators of support system. Lastly, the most powerful indicators of material hardship were items seven ($\beta = 0.96$, $p < .001$) and eight ($\beta = 0.95$, $p < .001$) on the food insecurity scale, and for socioeconomic stability it was not in receipt of benefits ($\beta = 0.79$, $p < .001$) and social rank ($\beta = 0.74$, $p < .001$).

However, four indicators had a factor loading just below 0.4, and although they were weaker, they were significant and met the minimal level of interpreting latent constructs (Hair et al., 2014). This included two items on the SDS-CL-17 (item six $\beta = 0.34$, $p < .001$; item eight $\beta = 0.35$, $p < .001$), being employed ($\beta = 0.39$, $p < .001$) and in a relationship ($\beta = 0.38$, $p < .001$). These were retained as they contributed to their respective latent variable and the overall model, in addition, they were statistically significant, where the model's fit suggested that they did not compromise the validity. In terms of the lower factor loading for the two items on the SDS-CL-17, which belonged to the sleep apnoea and circadian rhythm subscales, it is not uncommon for different but related items to have lower inter-item correlation across subscales and more strongly within subdomains (Clark & Watson, 2016; Nunnally & Bernstein 1994).

Structural paths: For the direct relationship between sleep disturbance, mental health and the exogenous variables (table 2), regression paths showed that increased material hardship (β = 0.44, $p < .001$), socioeconomic stability (β = 0.07, $p = .038$), being female (β = 0.06, $p = .005$), and having a minority sexual orientation (β = 0.06, $p = .011$) had a significant positive direct effect on sleep disturbance, indicating worse sleep. In contrast, increased age (β = -0.11, $p < .001$) and support system (β = -0.11, $p < .001$) were found to significantly predict sleep disturbance with a negative effect, suggesting that these factors were associated with better sleep. Non-significant predictors included declared religion (β = 0.03, $p = .137$) and ethnicity (β = 0.01, $p = .699$).

In relation to poorer mental health, this was strongly and significantly predicted by worse sleep disturbance (β = 0.55, $p < .001$) with a positive effect. Additionally, material hardship (β = 0.18, $p < .001$), being female (β = 0.06, $p < .001$) and having a minority sexual orientation (β = 0.06, $p < .001$) were also significant with positive effects, which suggested increased mental health difficulties. On the other hand, increased age (β = -0.18, $p < .001$), support system (β = -0.17, $p < .001$) and socioeconomic stability (β = -0.06, $p = .022$) had a significant negative effect with mental health, indicating better mental health. Similar to sleep, declared religion (β = -0.02, $p = .168$) and ethnicity (β = 0.01, $p = .620$) did not show significant effects on mental health.

Table 2

Direct effects.

Outcome	Predictor	β	Std. Error	*p*	95% CI Lower	95% CI Upper
Sleep disturbance	Gender (female)	0.06	0.02	.005	0.02	0.11
	Ethnicity (global majority)	0.01	0.02	.699	-0.04	0.05
	Age	-0.11	0.02	< .001	-0.16	-0.07
	Sexual orientation (minority)	0.06	0.02	.011	0.01	0.10
	Declared religion	0.03	0.02	.137	-0.01	0.07
	Support system	-0.11	0.03	< .001	-0.16	-0.06
	Material hardship	0.44	0.04	< .001	0.37	0.52
	Socioeconomic stability	0.07	0.03	.038	0.01	0.13
Mental health	Sleep disturbance	0.55	0.02	< .001	0.52	0.60
	Gender (female)	0.06	0.02	< .001	0.03	0.10
	Ethnicity (global majority)	0.01	0.02	.620	-0.03	0.04
	Age	-0.18	0.02	< .001	-0.22	-0.15
	Sexual orientation (minority)	0.06	0.02	< .001	0.02	0.09
	Declared religion (yes)	-0.02	0.02	.168	-0.06	0.01
	Support system	-0.17	0.02	< .001	-0.20	-0.13
	Material hardship	0.18	0.03	< .001	0.11	0.24
	Socioeconomic stability	-0.06	0.03	.022	-0.11	-0.01

Note. β = standardized beta coefficient; CI = confidence intervals.

Several indirect effects through sleep difficulties were identified (table 3). Support system (β = -0.06, $p < .001$) and age (β = -0.06, $p < .001$) had a significant negative indirect effect on mental health mediated via sleep disturbance. This suggested that increased support system and age lowered sleep difficulties, which then contributed to less mental health

difficulties. In contrast, material hardship (β = 0.25, $p < .001$), being female (β = 0.04, $p = .004$), and a minority sexual orientation (β = 0.03, $p = .011$) demonstrated a significant positive indirect effect on mental health mediated through sleep disturbance, which indicated that these factors led to increased sleep disturbance and successively worse mental health. Additionally, socioeconomic stability (β = 0.04, $p = .046$) showed a significant positive indirect effect on mental health mediated through sleep disturbance, suggesting increased mental health difficulties. Considering that the direct and indirect effects were in different directions, this reflected an inconsistent mediation, where the indirect pathway through sleep suppressed the protective direct effect of socioeconomic stability on mental health. Moreover, declaring a religion (β = 0.02, $p = .151$), and ethnicity (β = 0.01, $p = .709$) were not statistically significant.

Table 3

Indirect effects.

Variables	β	Std. Error	*p*	95% CI Lower	95% CI Upper
Gender (female) → Sleep → Mental health	0.04	0.01	.004	0.01	0.06
Ethnicity (global majority) → Sleep → Mental health	0.01	0.01	.709	-0.02	0.03
Age → Sleep → Mental health	-0.06	0.01	< .001	-0.09	-0.04
Sexual Orientation (minority) → Sleep → Mental health	0.03	0.01	.011	0.01	0.06
Declared religion → Sleep → Mental health	0.02	0.01	.151	-0.01	0.04
Support system → Sleep → Mental health	-0.06	0.01	< .001	-0.09	-0.03
Material hardship → Sleep → Mental health	0.25	0.02	< .001	0.20	0.29
Socioeconomic stability → Sleep → Mental health	0.04	0.02	.046	0.01	0.07

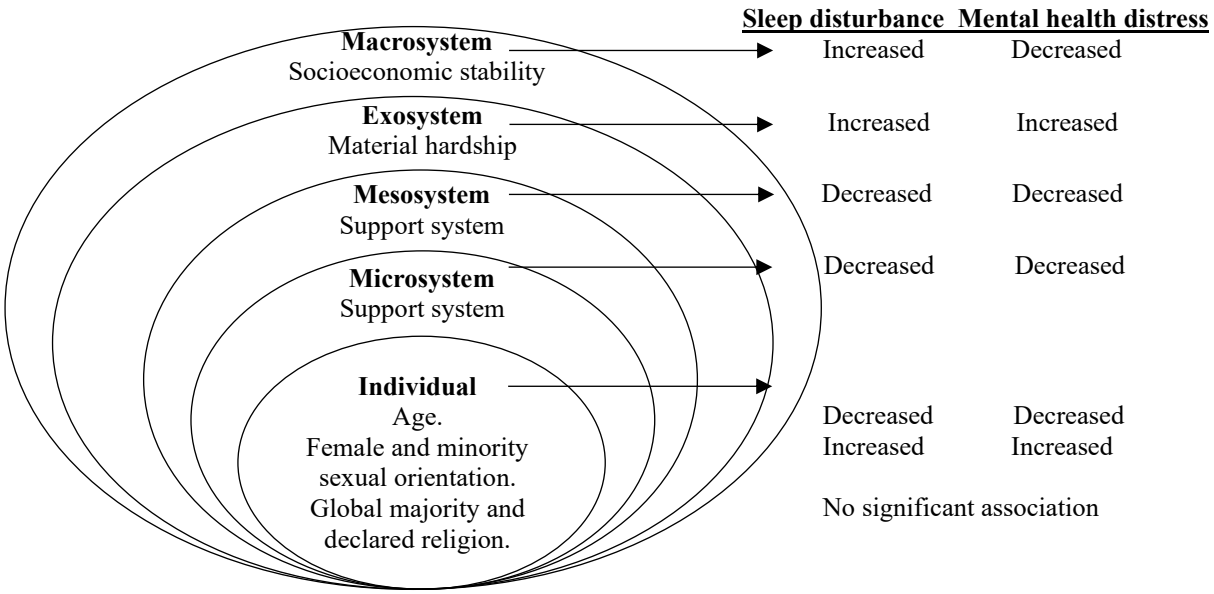
Note. β = standardized beta coefficient; CI = confidence intervals.

Discussion

This study sought to explore the association between sleep, mental health (depression, anxiety, psychotic experiences) and social determinants of mental health within Bronfenbrenner's framework, using SEM. The hypothesized model of the observed data had an excellent fit and the findings indicated that increased material hardship, socioeconomic stability, being female, and having a minority sexual orientation was associated with worse sleep disturbance, whilst increased age and support system were linked to better sleep. The same findings were observed for mental health, except for socioeconomic stability, which was associated with better mental health. Furthermore, increased sleep disturbance was linked to worse mental health, and it was found to mediate the relationship between mental health and support system, material hardship, socioeconomic stability, having a minority sexual orientation, being female and age. However, ethnicity or declaring a religion were not found to be associated with sleep nor mental health. These social determinants mapped on the Bronfenbrenner's framework (figure 2) and these findings are discussed further.

Figure 2

The findings applied to Bronfenbrenner's model



Certain social determinants were linked to poorer sleep. Specifically, material hardship was found to increase vulnerability for sleep related problems. This was in line with the literature, which has shown that sleep was affected by financial strain and stress (Bierman, 2021; Hall et al., 2009), including food insecurity (Mazloomi et al., 2023) and paying bills (Child et al., 2021). Material hardship aligned with the exosystem, which suggested potential interactions between indirect formal structures, such as the welfare system or minimum wage rates, and informal structures, for instance expensive groceries or high rent, which in turn worsened sleep. Indeed, welfare cuts has been found to be linked to poorer health (Gascoigne et al., 2023), whilst a higher minimum wage rate have been found to be linked with better health (Sotirakopoulos et al., 2025). A potential mechanism for this relationship could have been that material hardship increased uncertainty and stress (Pearlin, 1999), inducing physiological responses that interfered with sleep (Bierman, 2021).

Similarly to material hardship, higher levels of socioeconomic stability was associated with greater reports of sleep disturbances. Situated within the macrosystem, societal constructs, culture, and policies reward wealth through opportunities, status, and structural benefits (Beckert, 2024), yet this might also come at the cost of pressures and stressors reducing sleep. Although prior research predominantly reported opposing findings (Sosso et al., 2021), a narrative synthesis by Papadopoulos and Sosso (2023) reported that higher employment status and assets showed poorer sleep outcomes, whilst composite SES, encompassing income, employment and receipt of benefits, showed mixed findings. Subsequently, while socioeconomic stability might counteract financial and associated lifestyle stressors (Hall et al., 1999), other factors embodied within SES such as status and employment might in contrast raise stress (Akkiraju & Rao 2025; Schieman et al., 2009), which could increase arousal and interrupt sleep (Espie, 2002).

On a related note, although education has been proposed to be a prominent socioeconomic factor (Baker, 2014), having attended private secondary school did not load onto a latent construct nor was it associated with sleep or mental health. Considering that prior research has shown that higher educational attainment was linked to better sleep (Krueger & Friedman, 2009), this might have reflected that level of education could be more meaningful rather than the type of secondary school attended.

The foregoing findings highlighted how social support could act as a protective factor, where it was found to be associated with less sleep disturbance. These observations were in accordance with the wider literature, where social support (Kent de Grey et al., 2018), neighbourhood cohesion (Johnson et al., 2017) and being in a relationship (Hale, 2005) has been linked to better sleep. Support system, representing the microsystem and mesosystem, highlighted the influence from direct contact with the environment including a partner and neighbours, and interactions between these direct contacts, where the presence of these were linked to better sleep. A potential mechanism for this could have been that support networks mitigated the negative effect of life stressors (Cobb, 1976), whilst a lack of this could disrupt sleep (Johnson et al., 2017). Thus, this suggested that having a support system might buffer against external stressors and instead promote sleep.

In terms of individual characteristics, being female and having a minority sexual orientation was associated with worse sleep disturbance. Previous research has similarly found that having a minority sexual orientation has been linked to reduced sleep, which might reflect bullying and discrimination that could reduce sleep due to stressors (Leonard et al., 2025). Furthermore, the literature has also highlighted that poorer sleep was more prevalent for females compared to males (Zeng et al., 2020). In turn, this might reflect that women undertake a greater share of domestic labour, including childcare and housework (Byun et al., 2016), which could contribute to stress and less opportunities for restorative sleep (Ervin et

al., 2022). Consequently, while men might hold a parental status, women tend to undertake the majority of child caring responsibilities impacting sleep (Byun et al., 2016), which could have explained why being a parent or having children living in the household was not associated with sleep or mental health disparities.

Age was another factor examined by the current study, which showed that increased age was associated with better sleep. This did not align with the literature, where poorer sleep has been linked with normative aging (Calem et al., 2012). Considering that the sample of younger adults was smaller compared to the other groups, this might have reduced power for detecting an effect, yet some studies have reported similar findings (e.g., Gadie et al., 2017). Other possible explanations could have been that younger adults report higher levels of stress, ruminate on work before sleep (Hsu, 2019) and engage in more sleep incompatible lifestyle and behaviours compared to older adults, which could disrupt sleep (Gibson et al., 2023).

Further individual-level characteristics examined included belonging to the global majority and declaring a religion, where neither were associated with sleep or mental health. This was inconsistent with prior research, which has reported that being religious has been linked to better sleep or mental health (Ellison et al., 2011; Krause & Ironson, 2017), potentially due to providing support and comfort during hard times that could counteract stress (Hill et al., 2018). However, declaring a religion, might have reflected cultural norms and social aspects without a personal connection and engagement in religious practices or faith (Gans, 1994), where this distinction might have given rise to this discrepancy. The literature has similarly documented that individuals from the global majority experience poorer sleep (Billings et al., 2021; Groeger & Hepsomali, 2023), as a result of discrimination and racism inducing stress (Slopen et al., 2016). Nevertheless, other studies have revealed that those from the global majority who immigrated had better sleep compared to those who were native-born (Jackson et al., 2014; Jean-Louis et al., 2001). Correspondingly, this

suggested that the impact of ethnicity on sleep might be guided by a combination of factors, such as cultural practices, not fully captured in the present study.

Extending the focus to mental health, viewed through Bronfenbrenner's framework, both sleep disturbance and mental health were observed to be shaped by wider contextual systems. However, sleep also acted as a pathway through which these systems, spanning direct contacts, social, economic and cultural factors, influenced mental health, reflecting the pivotal role of sleep within the socioecological landscape. Although previous research has recognised some of these relationships (Hertenstein et al., 2019; Lund et al., 2018; McManus et al., 2016) and the mediating effect of sleep (Chai & Lu, 2025; Gu et al., 2024; Hale et al., 2013) an unexpected finding was that socioeconomic stability within the macrosystem increased mental health difficulties through sleep disturbance. While previous research has reported positive effects of higher SES on psychological wellbeing (Dougall et al., 2024), embedded work pressures could compromise sleep (Akkiraju & Rao 2025; Schieman et al., 2009) potentially offsetting any benefits.

Although some of these elements have been assessed previously (Grandner et al., 2015; Wu et al., 2025), no prior research appeared to have explored these multiple factors together within Bronfenbrenner's framework. Subsequently, this integrated understanding of individual characteristics and factors within the microsystem, mesosystem, exosystem, and macrosystem mirrored real-world experiences on sleep. These observations might have reflected stressors accompanied with the social determinants (e.g., Cohen & Wills 1985; Sinclair et al., 2024; Helpman, 2023), which increased cortisol (Smith & Vale, 2006) and arousal impacting sleep (Espie, 2002). In turn, sleep disturbance could have amplified amygdala reactivity and reduced connectivity with the medial-prefrontal cortex (Yoo et al., 2007), which contributed to emotional dysregulation and gave rise to worse mental health

(Walker & van Der Helm, 2009). Thus, this highlighted the important role of sleep as a central mechanism shaped by wider factors.

Strengths and Limitations

The cross-sectional nature of the study did not offer insight into longitudinal effects, yet it provided an understanding of the relationships between sleep disturbance, social determinants and mental health based on theory, where previous research has been limited. Furthermore, the sample was large and representative, which allowed for reliable and generalizable outcomes. However, the data was collected during the covid pandemic, which might have impacted behaviours and patterns (e.g., Pedrosa et al., 2020). Nevertheless, income was assessed based on 2019 income, very few participants (0.92%) were unemployed due to covid, and sleep was assessed based on experiences over the past year, reflecting stable patterns.

In relation to the data, a vast number of social determinants were examined, and sleep disturbance and mental health was assessed with validated measures, enhancing accuracy. However, as these were self-reported it could have led to social desirability bias or over/underestimation of sleep, where an objective measure could have provided accurate unbiased insight (Rundo & Downey, 2019). Moreover, the PSQ subscales were used rather than the individual items as indicators, which has been proposed to be acceptable in SEM (Vinnicombe et al., 2023). This approach was adopted due to the high dependency between each main item for each subscale and their respective follow-up items, which led to high levels of estimation instability marked by loading above 1 and artificial correlations. The hypomania subscale was also excluded due to the low factor loading, in line with other studies (e.g., $\beta = 0.14$; Thungana et al., 2023). A possible explanation for this could have been that hypomania was related to positive affect, whereas the other mental health indicators were

linked to negative states. Four other indicators had factor loading just below 0.4. However, these were included in the analysis as they were significant and met the minimal level for interpreting latent constructs (Hair et al., 2014). Two of these items belonged to the sleep apnoea and circadian rhythm subscales on the SDS-CL-17, which could have reflected less endorsement or lower inter-item correlation with the other subscales, which is not uncommon (Clark & Watson, 2016; Nunnally & Bernstein 1994).

In terms of the SEM model fit, $\chi 2$ for was significant, yet it has been asserted that it could be sensitive to large sample sizes (Bentler & Bonett, 1980). In contrast, the other fit indices, which have been considered to be more robust, indicated an excellent fit (Hu & Bentler, 1999). Furthermore, age showed reversed findings of what would be expected, and there was no association for ethnicity or declaring a religion on sleep or mental health as discussed earlier. Nevertheless, the author engaged in reflexivity, which could have reduced risk of bias and enhanced methodological rigor, trustworthiness to the data coding, findings and interpretations (Jamieson et al., 2023).

Implications and Future Research

Contained within the Bronfenbrenner's model, the findings framed sleep disturbance as a consequence of material hardship, support system, socioeconomic stability, and individual characteristics, which subsequently contributed to mental health difficulties. These findings likely have relevance across diverse settings, as housing, income and social support have been found to be globally significant (WHO, 2014). Further research is encouraged to examine the long-term effect of these relationships to determine causality.

In line with the upstream-downstream metaphor, this suggested taking an upstream approach by preventing underlying root causes of sleep disturbance, instead of a downstream position by reactively managing symptoms (McMahon, 2022). Subsequently, Clinical

Psychologists could contribute to a preventative public health approach (Harper, 2017) with a systemic focus on redistribution and social reforms (e.g., Corcoran, 2023) in collaboration with different stakeholders, including social services, local authorities, healthcare providers, educators, policymakers and people living in the community. Alongside this, Clinical Psychologists could advocate for policy change in welfare, reforms, and redistribution of resources. This could involve branching out and applying to strategic mental health roles within councils and population management projects, in addition to joining or collaborating with the British Psychological Society Public Health Divisions, taking advisory roles in Publica Health England or engage in co-productions. Within these forums, Clinical Psychologists could influence opinions by framing sleep as a public health priority, where formulations linking sleep, mental health, and social determinants could contribute to preventative policies, strategies and interventions. Clinical Psychologists could also integrate population-level and epidemiological data into these recommendations to allow for context sensitive formulations and interventions to target under-resourced areas or marginalised groups.

Several different areas could be targeted in these interventions and policies. Improving infrastructure for community-based support by setting up community and leisure centres, parks, and libraries could enhance social support. Additionally, material hardship and socioeconomic stability could be tackled through expanded welfare, food provision, employment and education opportunities, in addition to workplace wellness initiatives and revising laws around work hours and breaks. Furthermore, structural inequalities for marginalised groups could be addressed through access and inclusive anti-discriminatory laws, which could contribute to wider cultural and structural change. In turn, addressing these aspects might prevent sleep disturbance and successively mental health issues from arising in the first place. Further research might want to consider examining the impact of these

strategies, interventions and reforms on sleep disturbance. Subsequently, this could highlight changes and effectiveness for reversing sleep disturbance and areas for refinements.

Conclusion

The study's findings provided new insight into the relationships between sleep disturbance, mental health and social determinants within Bronfenbrenner's framework, where previous research has mainly assessed these factors in isolation or without theory. Material hardship (exosystem), socioeconomic stability (macrosystem), being female, and having a minority sexual orientation contributed to poorer sleep, whereas increased support system (microsystem and mesosystem) and age emerged as protective factors. Similar findings were shown for mental health, apart from the direction of socioeconomic stability, where sleep disturbance mediated the relationship between these factors. These findings highlighted how sleep disturbance was influenced by broader factors and acted as a pathway through which social determinants impacted mental health. A preventative public health approach could thus be taken to improve sleep, where future research is urged to assess the outcome from these strategies.

Reference

Adler, N. E., Epel, E. S., Castellazzo, G., & Ickovics, J. R. (2000). Relationship of subjective and objective social status with psychological and physiological functioning: Preliminary data in healthy, White women. *Health Psychology*, *19*(6), 586. https://doi.org/10.1037/0278-6133.19.6.586

Altena, E., & Ellis, J. G. (2021). How sleep affects daytime functioning: The latest insights from different patient and age groups. *Brain Sciences*, *11*(9), 1163. https://doi.org/10.3390/brainsci11091163

Akkiraju, K., & Rao, N. D. (2025). Higher income is associated with greater life satisfaction, and more stress. *Communications Psychology*, *3*(1), 27. https://doi.org/10.1038/s44271-025-00210-z

Arenas, D. J., Thomas, A., Wang, J., & DeLisser, H. M. (2019). A systematic review and meta-analysis of depression, anxiety, and sleep disorders in US adults with food insecurity. *Journal of General Internal Medicine*, *34*, 2874-2882. https://doi.org/10.1007/s11606-019-05202-4

Baglioni, C., Battagliese, G., Feige, B., Spiegelhalder, K., Nissen, C., Voderholzer, U., Lombardo, C., & Riemann, D. (2011). Insomnia as a predictor of depression: A meta-analytic evaluation of longitudinal epidemiological studies. *Journal of Affective Disorders*, *135*(1-3), 10-19. https://doi.org/10.1016/j.jad.2011.01.011

Baker, E. H (2014). Socioeconomic status, definition. In W. Cockerham, R. Dingwall, & S. Quah (Eds.), *The Wiley Blackwell encyclopedia of health, illness, behavior, and society* (pp. 2210–2214). Wiley Blackwell.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173. https://doi.org/10.1037/0022-3514.51.6.1173

Bebbington, P., & Nayani, T. (1995). The psychosis screening questionnaire. *International Journal of Methods in Psychiatric Research*, *5*(1), 11–19. https://doi.org/10.1037/t30040-000

Beckert, J. (2024). Varieties of wealth: Toward a comparative sociology of wealth inequality. *Socio-Economic Review, 22*(2), 475-499. http://doi.org/10.1093/ser/mwad068

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588. https://doi.org/10.1037/0033-2909.88.3.588

Beverly, S. G. (2001). Measures of material hardship: Rationale and recommendations. *Journal of Poverty, 5*(1), 23-41. https://doi.org/10.1300/J134v05n01_02

Bierman, A. (2021). Why have sleep problems in later-midlife grown following the great recession? A comparative cohort analysis. *The Journals of Gerontology: Series B*, *76*(5), 1005-1014. https://doi.org/10.1093/geronb/gbaa034

Billings, M. E., Cohen, R. T., Baldwin, C. M., Johnson, D. A., Palen, B. N., Parthasarathy, S., Parthasarathy, S., Patel, S. R., Russell, M., Tapia, I. E., Williamson, A. A., & Sharma, S. (2021). Disparities in sleep health and potential intervention models: A focused review. *Chest*, *159*(3), 1232-1240. https://doi.org/10.1016/j.chest.2020.09.249

Blanchflower, D. G., & Clark, A. E. (2021). Children, unhappiness and family finances. *Journal of Population Economics*, *34*(2), 625-653. https://doi.org/10.1007/s00148-020-00798-y

Brett, J. O., Staniszewska, S., Mockford, C., Herron-Marx, S., Hughes, J., Tysall, C., & Suleman, R. (2014). Mapping the impact of patient and public involvement on health and social care research: A systematic review. *Health Expectations*, *17*(5), 637-650. https://doi.org/10.1111/j.1369-7625.2012.00795.x

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist, 32*(7), 513. https://doi.org/10.1037/0003-066X.32.7.513

Brown, T. A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.). Guilford publications.

Butler, E. S., McGlinchey, E., & Juster, R. P. (2020). Sexual and gender minority sleep: A narrative review and suggestions for future research. *Journal of Sleep Research, 29*(1), e12928. https://doi.org/10.1111/jsr.12928

Byun, E., Lerdal, A., Gay, C. L., & Lee, K. A. (2016). How adult caregiving impacts sleep: A systematic review. *Current Sleep Medicine Reports*, *2*, 191-205. https://doi.org/10.1007/s40675-016-0058-8

Cabinet Office. (2015). *Community Life Survey technical report 2014-15.* Cabinet Office. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/470407/Community_Life_2014-15_Combined_technical_report_FINAL.pdf

Calem, M., Bisla, J., Begum, A., Dewey, M., Bebbington, P. E., Brugha, T., Cooper, C., Jenkins, R., Lindesay, J., McManus, S., Meltzer, H., Spiers, N., Weich, S., & Stewart,

R. (2012). Increased prevalence of insomnia and changes in hypnotics use in England over 15 years: Analysis of the 1993, 2000, and 2007 National Psychiatric Morbidity Surveys. *Sleep*, *35*(3), 377-384. https://doi.org/10.5665/sleep.1700

Chai, L., & Lu, Z. (2025). The association between financial strain and mental health: The mediating and moderating roles of sleep problems in the UK household longitudinal study (UKHLS). *Journal of Affective Disorders*, *377*, 245-253. https://doi.org/10.1016/j.jad.2025.02.060

Child, S., Ruppel, E. H., Zhong, M., & Lawton, L. (2021). Direct and moderating causal effects of network support on sleep quality: Findings from the UC Berkeley social network study. *Annals of Behavioral Medicine*, *55*(5), 446-459. https://doi.org/10.1093/abm/kaaa082

Clark, L. A., & Watson, D. (2016). Constructing validity: Basic issues in objective scale development. In A. E. Kazdin (Ed.), *Methodological issues and strategies in clinical research* (4th ed., pp. 187–203). American Psychological Association. https://doi.org/10.1037/14805-012

Cobb, S. (1976). Social support as a moderator of life stress. *Psychosomatic Medicine*, *38*(5), 300-314. https://doi.org/10.1097/00006842-197609000-00003

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Routledge.

Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. *Psychological Bulletin, 98*(2), 310. https://doi.org/10.1037/0033-2909.98.2.310

Cole, D. A., Ciesla, J. A., & Steiger, J. H. (2007). The insidious effects of failing to include design-driven correlated residuals in latent-variable covariance structure analysis. *Psychological Methods*, *12*(4), 381. https://doi.org/10.1037/1082-989X.12.4.381

Corcoran, R. (2023). Poverty, ACEs and stigmatised places: The application of psychology to the challenges of disadvantage. *Psychology and Psychotherapy: Theory, Research and Practice*, *96*(3), 577-589. https://doi.org/10.1111/papt.12457

Cormier, R. E. (1990). Sleep Disturbance. In H. K., Walker, W. D. Hall, & J. W. Hurst (Eds.), *Clinical Methods: The History, Physical, and Laboratory Examinations* (pp. 398-403). 3rd edition. Butterworths.

Cox, R. C., & Olatunji, B. O. (2016). A systematic review of sleep disturbance in anxiety and related disorders. *Journal of Anxiety Disorders*, *37*, 104-129. https://doi.org/10.1016/j.janxdis.2015.12.001

Dougall, I., Vasiljevic, M., Wright, J. D., & Weick, M. (2024). How, when, and why is social class linked to mental health and wellbeing? A systematic meta-review. *Social Science & Medicine*, *343*, 116542. https://doi.org/10.1016/j.socscimed.2023.116542

Early, E., & Devine, P. (2024). Men's health in Northern Ireland: Why do we need a men's health policy?. *Sociology of Health & Illness*, *46*(2), 236-256. https://doi.org/10.1111/1467-9566.13697

Ellison, C. G., Bradshaw, M., Storch, J., Marcum, J. P., & Hill, T. D. (2011). Religious doubts and sleep quality: Findings from a nationwide study of presbyterians. *Review of Religious Research*, *53*(2), 119-136. https://doi.org/10.1007/s13644-011-0019-0

Ervin, J., Taouk, Y., Alfonzo, L. F., Hewitt, B., & King, T. (2022). Gender differences in the association between unpaid labour and mental health in employed adults: A systematic review. *The Lancet Public Health*, *7*(9). https://doi.org/10.1016/S2468-2667(22)00160-8

España, R. A., & Scammell, T. E. (2011). Sleep neurobiology from a clinical perspective. *Sleep, 34*(7), 845-858. https://doi.org/10.5665/SLEEP.1112

Espie, C. A. (2002). Insomnia: Conceptual issues in the development, persistence, and treatment of sleep disorder in adults. *Annual Review of Psychology*, *53*(1), 215-243. https://doi.org/10.1146/annurev.psych.53.100901.135243

Food and Agricultural Organization. (2016). *Methods for estimating comparable rates of food insecurity experienced by adults throughout the world*. United Nations. https://www.fao.org/publications/card/en/c/2c22259f-ad59-4399-b740-b967744bb98d/

Gadie, A., Shafto, M., Leng, Y., & Kievit, R. A. (2017). How are age-related differences in sleep quality associated with health outcomes? An epidemiological investigation in a UK cohort of 2406 adults. *British Medical Journal Open*, *7*(7), e014920. https://doi.org/10.1136/bmjopen-2016-014920

Gascoigne, C., Blangiardo, M., Shao, Z., Jeffery, A., Geneletti, S., Kirkbride, J., & Baio, G. (2023). Bayesian Interrupted Time Series for evaluating policy change on mental well-being: an application to England's welfare reform. *arXiv preprint arXiv:2306.15525*. https://doi.org/10.48550/arXiv.2306.15525

Gans, H. J. (1994). Symbolic ethnicity and symbolic religiosity: Towards a comparison of ethnic and religious acculturation. *Ethnic and Racial Studies*, *17*(4), 577-592. https://doi.org/10.1080/01419870.1994.9993841

Gibson, R., Akter, T., Jones, C., & Towers, A. (2023). Characteristics of atypical sleep durations among older compared to younger adults: Evidence from the New Zealand Health Survey. *The Journals of Gerontology: Series A*, *78*(10), 1908-1918. https://doi.org/10.1093/gerona/glad042

Grandner, M. A., Hale, L., Moore, M., & Patel, N. P. (2010). Mortality associated with short sleep duration: The evidence, the possible mechanisms, and the future. *Sleep Medicine Reviews*, *14*(3), 191-203. https://doi.org/10.1016/j.smrv.2009.07.006

Grandner, M. A., Jackson, N. J., Izci-Balserak, B., Gallagher, R. A., Murray-Bachmann, R., Williams, N. J., Patel, N. P., & Jean-Louis, G. (2015). Social and behavioral determinants of perceived insufficient sleep. *Frontiers in Neurology*, *6*, 112. https://doi.org/10.3389/fneur.2015.00112

Groeger, J. A., & Hepsomali, P. (2023). Social deprivation and ethnicity are associated with more problematic sleep in middle-aged and older adults. *Clocks & Sleep*, *5*(3), 399-413. https://doi.org/10.3390/clockssleep5030030

Gu, Y., Hu, P., Ren, H., Dai, C., He, X., Cheng, W., Yu, L., Fang, A., Meng, X., Lou, M., Chen, Y., Chi1, D., Zhou, H., Chen, O., Ni1, S., & Huang, Q. (2024). The mediating effect of sleep quality on the relationship between social support and depressive symptoms among Chinese nurses during the omicron outbreak. *British Medical Council Psychiatry*, *24*(1), 915. https://doi.org/10.1186/s12888-024-06326-6

Hafner, M., Stepanek, M., Taylor, J., Troxel, W. M., & Van Stolk, C. (2017). Why sleep matters—the economic costs of insufficient sleep: A cross-country comparative analysis. *Rand Health Quarterly*, *6*(4). https://doi.org/10.7249/RR1791

Hair J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate data analysis* (7th ed, pp. 89-150). Pearson Education Limited.

Hale, L. (2005). Who has time to sleep?. *Journal of Public Health*, *27*(2), 205-211. https://doi.org/10.1093/pubmed/fdi004

Hale, L., Hill, T. D., Friedman, E., Nieto, F. J., Galvao, L. W., Engelman, C. D., Malecki, K. M. C., & Peppard, P. E. (2013). Perceived neighborhood quality, sleep quality, and health status: Evidence from the Survey of the Health of Wisconsin. *Social Science & Medicine*, *79*, 16-22. https://doi.org/10.1016/j.socscimed.2012.07.021

Hale, L., Troxel, W., & Buysse, D. J. (2020). Sleep health: An opportunity for public health to address health equity. *Annual Review of Public Health*, *41*, 81-99. https://doi.org/10.1146/annurev-publhealth-040119-094412

Hall, M., Bromberger, J., & Matthews, K. (1999). Socioeconomic status as a correlate of sleep in African-American and Caucasian women. *Annals of the New York Academy of Sciences*, *896*(1), 427-430. https://doi.org/10.1111/j.1749-6632.1999.tb08161.x

Hall, M. H., Matthews, K. A., Kravitz, H. M., Gold, E. B., Buysse, D. J., Bromberger, J. T., Owens, J. F., & Sowers, M. (2009). Race and financial strain are independent correlates of sleep in midlife women: The SWAN sleep study. *Sleep*, *32*(1), 73-82. https://doi.org/10.5665/sleep/32.1.73

Harper, D. (2017). The promise (and potential pitfalls) of a public health approach in clinical psychology. *Clinical Psychology Forum*, 297, 23-32. https://doi.org/10.53841/bpscpf.2017.1.297.23

Helpman, L. (2023). On the stress of being a woman: The synergistic contribution of sex as a biological variable and gender as a psychosocial one to risk of stress-related disorders. *Neuroscience & Biobehavioral Reviews*, *150*, 105211. https://doi.org/10.1016/j.neubiorev.2023.105211

Hertenstein, E., Feige, B., Gmeiner, T., Kienzler, C., Spiegelhalder, K., Johann, A., Jansson-Fröjmark, M., Palagini, L., Rücker, G., Riemann, D., & Baglioni, C. (2019). Insomnia

as a predictor of mental disorders: A systematic review and meta-analysis. *Sleep Medicine Reviews*, *43*, 96-105. https://doi.org/10.1016/j.smrv.2018.10.006

Hill, T. D., Deangelis, R., & Ellison, C. G. (2018). Religious involvement as a social determinant of sleep: An initial review and conceptual model. *Sleep Health*, *4*(4), 325-330. https://doi.org/10.1016/j.sleh.2018.04.001

Hsu, H. C. (2019). Age differences in work stress, exhaustion, well-being, and related factors from an ecological perspective. *International Journal of Environmental Research and Public Health*, *16*(1), 50. https://doi.org/10.3390/ijerph16010050

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Jackson, C. L., Hu, F. B., Redline, S., Williams, D. R., Mattei, J., & Kawachi, I. (2014). Racial/ethnic disparities in short sleep duration by occupation: The contribution of immigrant status. *Social Science & Medicine*, *118*, 71-79. https://doi.org/10.1016/j.socscimed.2014.07.059

Jamieson, M. K., Govaart, G. H., & Pownall, M. (2023). Reflexivity in quantitative research: A rationale and beginner's guide. *Social and Personality Psychology Compass*, *17*(4), e12735. https://doi.org/10.1111/spc3.12735

Jansson-Fröjmark, M., & Lindblom, K. (2008). A bidirectional relationship between anxiety and depression, and insomnia? A prospective study in the general population. *Journal of Psychosomatic Research*, *64*(4), 443-449. https://doi.org/10.1016/j.jpsychores.2007.10.016

Jean-Louis, G., Magai, C. M., Cohen, C. I., Zizi, F., von Gizycki, H., DiPalma, J., & Casimir, G. J. (2001). Ethnic differences in self-reported sleep problems in older adults. *Sleep, 24*(8), 926-933. https://doi.org/10.1093/sleep/24.8.926

Johnson, D. A., Simonelli, G., Moore, K., Billings, M., Mujahid, M. S., Rueschman, M., Kawachi, I., Redline, S., Diez Roux, A. V., & Patel, S. R. (2017). The neighborhood social environment and objective measures of sleep in the multi-ethnic study of atherosclerosis. *Sleep*, *40*(1). https://doi.org/10.1093/sleep/zsw016

Kent de Grey, R. G., Uchino, B. N., Trettevik, R., Cronan, S., & Hogan, J. N. (2018). Social support and sleep: A meta-analysis. *Health Psychology*, *37*(8), 787. https://doi.org/10.1037/hea0000628

Klingman, K. J., Jungquist, C. R., & Perlis, M. L. (2017). Introducing the sleep disorders symptom checklist-25: A primary care friendly and comprehensive screener for sleep disorders. *Sleep Medicine Research*, *8*(1), 17-25. https://doi.org/10.17241/smr.2017.00010

Krause, N., & Ironson, G. (2017). Is involvement in religion associated with better sleep quality?. *Pastoral Psychology*, *66*, 595-608. https://doi.org/10.1007/s11089-017-0766-0

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606-613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Krueger, P. M., & Friedman, E. M. (2009). Sleep duration in the United States: A cross-sectional population-based study. *American Journal of Epidemiology*, *169*(9), 1052-1063. https://doi.org/10.1093/aje/kwp023

Laaksonen, E., Martikainen, P., Lahelma, E., Lallukka, T., Rahkonen, O., Head, J., & Marmot, M. (2007). Socioeconomic circumstances and common mental disorders among Finnish and British public sector employees: Evidence from the Helsinki Health Study and the Whitehall II Study. *International Journal of Epidemiology, 36*(4), 776-786. https://doi.org/10.1093/ije/dym074

Leonard, S. I., Castiblanco, M., Chang, A., Belloir, J., Caceres, B. A., Bruzzese, J. M., & Jackman, K. B. (2025). Sleep health among sexual and gender minority people in the United States: A scoping review. *Sleep Medicine*, *128*, 12-21. https://doi.org/10.1016/j.sleep.2024.12.033

Li, C. H. (2016). The performance of ML, DWLS, and ULS estimation with robust corrections in structural equation models with ordinal variables. *Psychological Methods*, *21*(3), 369–387. https://doi.org/10.1037/met0000093

Li, J. (2024). The relationship between peer support and sleep quality among Chinese college students: The mediating role of physical exercise atmosphere and the moderating effect of eHealth literacy. *Frontiers in Psychology*, *15*, 1422026. https://doi.org/10.3389/fpsyg.2024.1422026

Li, L., Wu, C., Gan, Y., Qu, X., & Lu, Z. (2016). Insomnia and the risk of depression: A meta-analysis of prospective cohort studies. *BioMed Central Psychiatry*, *16*(1), 1-16. https://doi.org/10.1186/s12888-016-1075-3

Lund, C., Brooke-Sumner, C., Baingana, F., Baron, E. C., Breuer, E., Chandra, P., Haushofer, J., Herrman, H., Jordans, M., Kieling, C., Medina-Mora, M. E., Morgan, E., Omigbodun, O., Tol, W., Patel, V., & Saxena, S. (2018). Social determinants of mental disorders and the Sustainable Development Goals: A systematic review of

reviews. *The Lancet Psychiatry*, *5*(4), 357-369. https://doi.org/10.1016/S2215-0366(18)30060-9

MacCallum, R. C. (1995). Model specification: Procedures, strategies, and related issues. In R. H. Hoyle (Ed.), *Structural equation modeling: Concepts, issues, and applications* (pp. 16-36). Sage publication.

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual Review of Psychology*, *51*(1), 201-226. https://doi.org/10.1146/annurev.psych.51.1.201

Mazloomi, S. N., Talebi, S., Kazemi, M., Ghoreishy, S. M., Moosavian, S. P., Amirian, P., Mohammadi, H., Nouri-Majd, S., Marx, W., Kermani, M. A. H., & Moradi, S. (2023). Food insecurity is associated with the sleep quality and quantity in adults: A systematic review and meta-analysis. *Public Health Nutrition*, *26*(4), 792-802. https://doi.org/10.1017/S1368980022002488

McBride, O., Butter, S., Murphy, J., Hartman, T. K., McKay, R., Hyland, P., Shevlin, M., Bennett, K. M., Stocks, T. V. A., Lloyd, A., Gibson-Miller, J., Levita, L., Mason, L., Martinez, A. P., Vallières, F., Karatzias, T., & Bentall, R. P. (2022a). Tracking the psychological and socio-economic impact of the COVID-19 pandemic in the UK: A methodological report from Wave 5 of the COVID-19 Psychological Research Consortium (C19PRC) Study. *International Journal of Methods in Psychiatric Research*, e1928. https://doi.org/10.1002/mpr.1928

McBride, O., Butter, S., Murphy, J., Shevlin, M., Hartman, T. K., Bennett, K. M., Stocks. T. V. A., Lloyd. A., McKay. R., Gibson-Miller. J., Levita. L., Mason. L., Martinez. A. P., Hyland. P., Vallières. F., Karatzias. T., Valiente. C., Vazquez. C., & Bentall, R. P. (2022b). Design, content, and fieldwork procedures of the COVID-19 Psychological

Research Consortium (C19PRC) Study–Wave 4. *International Journal of Methods in Psychiatric Research*, *31*(1), e1899. https://doi.org/10.1002/mpr.1899

McGrath, J. J., Saha, S., Al-Hamzawi, A. O., Alonso, J., Andrade, L., Borges, G., Bromet, E. J., Browne, M. O., Bruffaerts, R., Caldas de Almeida, J. M., Fayyad, J., Florescu, S., de Girolamo, G., Gureje, O., Hu, C., de Jonge, P., Kovess-Masfety, V., Lepine, J. P., Lim, C. C. W., Navarro-Mateu, F., Piazza, M., Sampson, N., Posada-Villa, J., Kendler, K. S., & Kessler, R. C. (2016). Age of onset and lifetime projected risk of psychotic experiences: Cross-national data from the World Mental Health Survey. *Schizophrenia Bulletin*, *42*(4), 933-941. https://doi.org/10.1093/schbul/sbw011

McGuffog, R., Rubin, M., Boyes, M., Caltabiano, M. L., Collison, J., Lovell, G. P., Muldoon, O., & Paolini, S. (2023). Sleep as a mediator of the relationship between social class and health in higher education students. *British Journal of Psychology*, *114*(3), 710-730. https://doi.org/10.1111/bjop.12645

McGuire, K., Andrews, A., Bogle, M., & Carril, A. (2024). Exploration of Sleep Health and Behaviors Among Undergraduate Nursing Students. *Nursing Education Perspectives*, 10-1097. https://doi.org/10.1097/01.NEP.0000000000001337

McMahon, N. E. (2022). Framing action to reduce health inequalities: What is argued for through use of the 'upstream–downstream'metaphor?. *Journal of Public Health*, *44*(3), 671-678. https://doi.org/10.1093/pubmed/fdab157

McManus, S., Bebbington, P., Jenkins, R., & Brugha, T. (2016). *Mental health and wellbeing in England: Adult Psychiatric Morbidity Survey 2014*. NHS Digital. https://assets.publishing.service.gov.uk/media/5a802e2fe5274a2e8ab4ea71/apms-2014-full-rpt.pdf

Memon, M. A., Jun, H. C., Ting, H., & Francis, C. W. (2018). Mediation analysis issues and recommendations. *Journal of Applied Structural Equation Modeling*, *2*(1), i-ix. https://doi.org/10.47263/JASEM.2(1)01

Moore, P. J., Adler, N. E., Williams, D. R., & Jackson, J. S. (2002). Socioeconomic status and health: The role of sleep. *Psychosomatic Medicine*, *64*(2), 337-344. https://doi.org/10.1097/00006842-200203000-00018

Morin, C. M., & Benca, R. (2012). Chronic insomnia. *The Lancet*, *379*(9821), 1129-1141. https://doi.org/10.1016/S0140-6736(11)60750-2

Morris, M., Alencar, Y., Rachet, B., Stephens, R., & Coleman, M. P. (2020). Fleshing out the data: When epidemiological researchers engage with patients and carers. Learning lessons from a patient involvement activity. *British Medical Journal Open*, *10*(9), e036311. https://doi.org/10.1136/bmjopen-2019-036311

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed., pp. 225-275). McGraw-Hill.

Papadopoulos, D., & Sosso, F. A. E. (2023). Socioeconomic status and sleep health: A narrative synthesis of 3 decades of empirical research. *Journal of Clinical Sleep Medicine*, *19*(3), 605-620. https://doi.org/10.5664/jcsm.10336

Pearlin, L. I. (1999). The stress process revisited: Reflections on concepts and their inter-relationships. In C. S. Aneshensel & J. C. Phelan (Eds.), *Handbook of the sociology of mental health* (pp. 395–415). Kluwer Academic/Plenum.

Pedrosa, A. L., Bitencourt, L., Fróes, A. C. F., Cazumbá, M. L. B., Campos, R. G. B., De Brito, S. B. C. S., & Simões e Silva, A. C. (2020). Emotional, behavioral, and

psychological impact of the COVID-19 pandemic. *Frontiers in Psychology*, *11*, 566212. https://doi.org/10.3389/fpsyg.2020.566212

Person, J. E. (1986). The definition and measurement of social support. *Journal of Counseling & Development*, *64*(6). https://doi.org/10.1002/j.1556-6676.1986.tb01144.x

Pigeon, W. R., Bishop, T. M., & Krueger, K. M. (2017). Insomnia as a precipitating factor in new onset mental illness: A systematic review of recent findings. *Current Psychiatry Reports*, *19*, 1-11. https://doi.org/10.1007/s11920-017-0802-x

Post, D., & Veling, W. (2021). Sexual minority status, social adversity and risk for psychotic disorders-results from the GROUP study. *Psychological Medicine*, *51*(5), 770-776. https://doi.org/10.1017/S0033291719003726

Pourmotabbed, A., Moradi, S., Babaei, A., Ghavami, A., Mohammadi, H., Jalili, C., Symonds, M. E., & Miraghajani, M. (2020). Food insecurity and mental health: A systematic review and meta-analysis. *Public Health Nutrition*, *23*(10), 1778-1790. https://doi.org/10.1017/S136898001900435X

Reeve, S., Sheaves, B., & Freeman, D. (2015). The role of sleep dysfunction in the occurrence of delusions and hallucinations: A systematic review. *Clinical Psychology Review*, *42*, 96-115. https://doi.org/10.1016/j.cpr.2015.09.001

Rhemtulla, M., Brosseau-Liard, P. É., & Savalei, V. (2012). When can categorical variables be treated as continuous? A comparison of robust continuous and categorical SEM estimation methods under suboptimal conditions. *Psychological Methods*, *17*(3), 354. https://doi.org/10.1037/a0029315

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*, 1-36. https://doi.org/10.18637/jss.v048.i02

Rosseel, Y., Jorgensen, T. D., De Wilde, L., Oberski, D., Byrnes, J., Vanbrabant, L., Savalei, V., Merkle, E., Hallquist, M., Rhemtulla, M., Katsikatsou, M., Barendse, M., Rockwood, M., Scharf, F., Du, H., Jamil, H., & Classe, F. (2024). Package 'lavaan'. https://cran.r-project.org/web/packages/lavaan/lavaan.pdf

Sanders, G. F., Fitzgerald, M. A., & Bratteli, M. (2008). Mental health services for older adults in rural areas: An ecological systems approach. *Journal of Applied Gerontology*, *27*(3), 252-266. https://doi.org/10.1177/0733464807311646

Savarimuthu, J. R., & Subramanian, K. (2022). Associations between digital amnesia, sleep disorders and somatic symptoms among youth. *Cognition, Brain, Behavior*, *26*(2), 121-135. https://doi.org/10.24193/cbb.2022.26.07

Schieman, S., Glavin, P., & Milkie, M. A. (2009). When work interferes with life: Work-nonwork interference and the influence of work-related demands and resources. *American Sociological Review*, *74*(6), 966-988. https://doi.org/10.1177/000312240907400606

Sinclair, R. R., Graham, B. A., & Probst, T. M. (2024). Economic stress and occupational health. *Annual Review of Organizational Psychology and Organizational Behavior, 11*(1), 423-451. https://doi.org/10.1146/annurev-orgpsych-091922-020639

Slopen, N., Lewis, T. T., & Williams, D. R. (2016). Discrimination and sleep: A systematic review. *Sleep Medicine*, *18*, 88-95. https://doi.org/10.1016/j.sleep.2015.01.012

Smith, S. M., & Vale, W. W. (2006). The role of the hypothalamic-pituitary-adrenal axis in neuroendocrine responses to stress. *Dialogues in Clinical Neuroscience*, *8*(4), 383-395. https://doi.org/10.31887/DCNS.2006.8.4/ssmith

Sosso, F. A. E., Holmes, S. D., & Weinstein, A. A. (2021). Influence of socioeconomic status on objective sleep measurement: A systematic review and meta-analysis of actigraphy studies. *Sleep Health*, *7*(4), 417-428. https://doi.org/10.1016/j.sleh.2021.05.005

Sotirakopoulos, P., Guven, C., Ulker, A., & Graham, C. (2025). The impact of minimum wages on overall health and well-being: Global evidence from the Gallup World Poll. *Social Science & Medicine*, *375*, 118064. https://doi.org/10.1016/j.socscimed.2025.118064

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092-1097. https://doi.org/10.1001/archinte.166.10.1092

Sturgeon, S. (2006). Promoting mental health as an essential aspect of health promotion. *Health Promotion International*, *21*(suppl_1), 36-41. https://doi.org/10.1093/heapro/dal049

Thungana, Y., Zingela, Z., van Wyk, S., Kim, H. H., Ametaj, A., Stevenson, A., Stroud, R. E., Stein, D. J., & Gelaye, B. (2023). Psychosis screening questionnaire: Exploring its factor structure among South African adults. *South African Journal of Psychiatry, 29*(1). https://doi.org/10.4102/sajpsychiatry.v29i0.2051

Tomlinson, J., Medlinskiene, K., Cheong, V. L., Khan, S., & Fylan, B. (2019). Patient and public involvement in designing and conducting doctoral research: The whys and the hows. *Research Involvement and Engagement*, *5*, 1-12. https://doi.org/10.1186/s40900-019-0155-1

van Doorn, J., Tanis, C., & Burger, J. (2019). Structural equation modelling: JASP manual. https://osf.io/x6zeb/

Vinnicombe, S., Bianchim, M. S., & Noyes, J. (2023). A review of reviews exploring patient and public involvement in population health research and development of tools containing best practice guidance. *BioMed Central Public Health*, *23*(1), 1271. https://doi.org/10.1186/s12889-023-15937-9

Walker, D. A., & Smith, T. J. (2020). Logistic regression under sparse data conditions. *Journal of Modern Applied Statistical Methods*, *18*(2), 25. https://doi.org/10.22237/jmasm/1604190660

Walker, M. P., & van Der Helm, E. (2009). Overnight therapy? The role of sleep in emotional brain processing. *Psychological Bulletin*, *135*(5), 731. https://doi.org/10.1037/a0016570

Wang, Y. A., & Rhemtulla, M. (2021). Power analysis for parameter estimation in structural equation modeling: A discussion and tutorial. *Advances in Methods and Practices in Psychological Science*, *4*(1), 1–17. https://doi.org/10.1177/2515245920918253

World Health Organization. (2014). *Social determinants of mental health.* World Health Organization. https://www.who.int/publications/i/item/9789241506809

Wu, C., Chau, P. H., & Choi, E. P. H. (2025). Exploring social-ecological pathways from sexual identity to sleep among Chinese women: Structural equation modeling analysis. *Journal of Medical Internet Research Public Health and Surveillance*, *11*(1), e53549. https://doi.org/10.2196/53549

Yakushko, O., & Chronister, K. M. (2005). Immigrant women and counseling: The invisible others. *Journal of Counseling & Development*, *83*(3), 292-298. https://doi.org/10.1002/j.1556-6678.2005.tb00346.x

Yoo, S. S., Gujar, N., Hu, P., Jolesz, F. A., & Walker, M. P. (2007). The human emotional brain without sleep—a prefrontal amygdala disconnect. *Current Biology*, *17*(20), R877-R878. https://doi.org/10.1016/j.cub.2007.08.007

Zeng, L. N., Zong, Q. Q., Yang, Y., Zhang, L., Xiang, Y. F., Ng, C. H., Chen, L-G., & Xiang, Y. T. (2020). Gender difference in the prevalence of insomnia: A meta-analysis of observational studies. *Frontiers in Psychiatry*, *11*, 577429. https://doi.org/10.3389/fpsyt.2020.577429

Zhang, R., Peng, X., Song, X., Long, J., Wang, C., Zhang, C., Huang, R., & Lee, T. M. (2023). The prevalence and risk of developing major depression among individuals with subthreshold depression in the general population. *Psychological Medicine*, *53*(8), 3611-3620. https://doi.org/10.1017/S0033291722000241

Zhong, Q., Niu, L., Chen, K., Lee, T. M., & Zhang, R. (2024). Prevalence and risk of subthreshold anxiety developing into threshold anxiety disorder in the general population. *Journal of Affective Disorders*, *367*, 815-822. https://doi.org/10.1016/j.jad.2024.09.031

Appendices

Appendix A

Letter from the University Research Ethics Committee

Downloaded: 15/01/2024
Approved: 15/01/2024

Linda-Mary Eriksson
Registration number: 220238029
Psychology
Programme: Doctorate in Clinical Psychology

Dear Linda-Mary

PROJECT TITLE: Social Determinants of Mental Health and Distress as Concomitants of Sleep Disturbance: A Structural Equation Modelling Approach
APPLICATION: Reference Number 057562

This letter confirms that you have signed a University Research Ethics Committee-approved self-declaration to confirm that your research will involve only existing research, clinical or other data that has been robustly anonymised. You have judged it to be unlikely that this project would cause offence to those who originally provided the data, should they become aware of it.

As such, on behalf of the University Research Ethics Committee, I can confirm that your project can go ahead on the basis of this self-declaration.

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since full ethical review may be required.

Yours sincerely

Department Of Psychology Research Ethics Committee
Departmental Ethics Administrator

Appendix B

Participant Information Sheet

Participant Information Sheet

The COVID-19 pandemic in the UK: One year since lockdown

Last year, you participated in one or more surveys examining the possible psychological and social effects of the coronavirus (COVID-19) pandemic - thank you. Your participation is greatly appreciated and has been invaluable in helping us to understand the UK's experience of the pandemic. It has now been one year since the UK government first imposed a 'lockdown'. We would like to now invite you to participate in a follow-up survey for this same study. Before you decide whether you would like to take part, please read the following information to ensure that you understand what it involves.

What is the purpose of the study and what does it involve? This survey is part of a wider study to understand how the pandemic is affecting the lives of ordinary people over time. We hope that the findings from this survey will be used to make recommendations about how to best manage this and future pandemics and similar crises. We are therefore asking you to complete a series of questionnaires online, which you will be taken to after this invitation. We will ask you about your experiences of the pandemic (e.g. whether you have been infected with coronavirus), your knowledge and attitudes towards the coronavirus pandemic (e.g. what are your thoughts about a vaccine for the coronavirus); your health and well-being (e.g., physical health, mood, fears, unusual experiences) and your home life during the pandemic, as well as your social attitudes (e.g., political beliefs).

We will also ask you about some topics which may be considered sensitive (e.g. difficult childhood experiences) but you do not have to complete this section of the survey and will have the option to skip these questions.

You may have answered some of these questions in previous surveys you completed; however, it will be very helpful to us if you answer these questions again so that we can understand how your views may be changing during the pandemic. The survey will take you approximately 30 minutes to complete. We may contact you again in the future to further understand how your life is affected as the months pass, but you will be free to refuse to Page 2 of 164 participate at that stage if you then decide that you no longer want to be involved in this study.

Do I have to take part? Participation is on a voluntary basis. If you do decide to take part, you can withdraw at any time. You will not be asked to provide a reason for withdrawing.

What are the possible disadvantages and risks of taking part? We anticipate no risk of harm from taking part in this study, although some of the questions may be quite personal. If for any reason you experience any discomfort and feel that you can no longer continue, you may withdraw from the study by just shutting down the browser. If you are worried about COVID-19, you might find it helpful to visit the UK Government's COVID-19 website https://www.gov.uk/coronavirus. If you are concerned or distressed by any of the topics covered in the survey, you might find it helpful to seek support from your GP.

Will my participation in this project be kept confidential? Your data will be treated as anonymous, and you will not be identifiable by the information that you provide to us. However, we will record your computer's IP address. We will use the IP address (and the first part of your postcode which you may have provided during a previous survey) to locate the neighbourhood in which you live and to find out what kind of area it is; for example, how many people live in your area and how many people from your area become ill due to COVID-19 in the future. Once we have this information, we will erase your postcode

information and IP address from the database. Hence, there will be no possibility of linking the information you provide directly back to you.

We will share the data with other scientists who may want to use it. However, we will require them to observe the highest ethical standards when using it.

What is the legal basis for processing my personal data? According to data protection legislation, we are required to inform you that the legal basis we are applying in order to process your data is that 'processing is necessary for the performance of a task carried out in the public interest' (Article 6(1)(e)). Further information can be found in the University's Privacy Notice https://www.sheffield.ac.uk/govern/dataprotection/privacy/general

Who is organising and funding the research? Researchers at the University of Sheffield, Ulster University, University of Liverpool, and University College London are conducting this study. It is funded by the UK Research and Innovation's Economic and Social Research Council.

Who is the Data Controller? The University of Sheffield is the Data Controller for this study. This means that University of Page 3 of 164 Sheffield is responsible for looking after your information and using it properly.

What will happen to the data collected, and the results of the research project? When the results of the study are published in a scientific journal, you will not be identifiable. Your data will be stored anonymously, with all personal information removed.

Who has ethically reviewed the project? Ethical approval was obtained from the University of Sheffield, Department of Psychology Ethics Committee.

What if something goes wrong and I wish to complain about the research? If you have any concerns or complaints about the study, you may contact Dr Sarah Butter (s.butter@sheffield.ac.uk) directly.

Also, you can contact the chief investigator: Professor Richard Bentall (r.bentall@sheffield.ac.uk)

Alternatively, if your complaint has not been handled to your satisfaction you may contact Professor Elizabeth Milne (Head of the Psychology Department; psy-hod@sheffield.ac.uk).

Contact for further information: If you have any questions regarding this study, please feel free to contact Sarah Butter or the chief investigator Richard Bentall (details provided above).

Thank you for taking part in this study.

Appendix C

Consent form

CONSENT TO TAKING PART

Please read and tick the statements below to indicate your consent to take part in the research.

You must agree to all of these statements in order to participate.

Please tick the appropriate boxes

Taking Part in the Project

Consent1 I have read and understood the project information page. (If 'No' survey terminated.)

o Yes

o No

Skip To: End of Block If I have read and understood the project information page. (If 'No' survey terminated.) = No

Consent2 I understand that my taking part is voluntary and that I can withdraw from the study at any time while I am completing the survey; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw. (If 'No' survey terminated.)

o Yes

o No

Skip To: End of Block If I understand that my taking part is voluntary and that I can withdraw from the study at any tim... = No

Consent3 I understand that my geolocation data is going to be collected as part of demographic information and that this data will be treated as strictly confidential. (If ‘No’ survey terminated.)

o Yes

o No

Skip To: End of Block If I understand that my geolocation data is going to be collected as part of demographic information... = No

How my information will be used during and after the project

Consent4 I understand and agree that other authorised researchers will have access to the data from this survey only if they agree to preserve the confidentiality of the information as requested in this form. (If ‘No’ survey terminated.)

o Yes

o No

Skip To: End of Block If I understand and agree that other authorised researchers will have access to the data from this s... = No

Consent5 I understand that no information that identifies me will be revealed in any reports or publications that arise from this survey. (If ‘No’ survey terminated.)

o Yes

o No

Skip To: End of Block If I understand that no information that identifies me will be revealed in any reports or publicatio... = No

Consent6 **Project contact details for further information:** Prof. Richard Bentall (Primary Researcher; email: r.bentall@sheffield.ac.uk) Dr Sarah Butter (Researcher; email: s.butter@sheffield.ac.uk) Prof. Elizabeth Milne (Head of Psychology Department; psy-hod@sheffield.ac.uk)

Address: Cathedral Court, 1 Vicar Lane, S1 2LT

Appendix D

Sleep Disorders Symptom Checklist-17

Sleep Disorders Symptom Checklist-17

Over the past year…

		Never	Seldom (Once a year)	Sometimes (1 - 3 times per month)	Often (1 - 3 times per week)	Frequently (More than 3 times per week)
1.	It takes me 30 minutes or more to fall asleep.	o	o	o	o	o
2.	I am awake 30 minutes or more during the night.	o	o	o	o	o
3.	I am awake 30 minutes or more prior to my scheduled wake time or alarm.	o	o	o	o	o
4.	I am tired, fatigued or sleepy during the day.	o	o	o	o	o
5.	I sleep better if I go to bed before 9:00 pm and wake up before 5:30 am.	o	o	o	o	o
6.	I sleep better if I go to bed late (after 1:00 am) and wake up late (after 9:00 am).	o	o	o	o	o
7.	I fall asleep at inappropriate times or places.	o	o	o	o	o
8.	I have been told that I snore.	o	o	o	o	o
9.	I wake up during the night choking or gasping.	o	o	o	o	o
10.	I have been told I stop breathing when I sleep.	o	o	o	o	o
11.	I feel uncomfortable sensations in my legs, especially when sitting or lying down that are relieved by moving them.	o	o	o	o	o

12.	I have an urge to move my legs that is worse in the evenings and nights.	o	o	o	o	o
13.	I wake up frequently during the night for no reason.	o	o	o	o	o
14.	I have experienced sudden muscle weakness when laughing, joking, angry or during other intense emotions.	o	o	o	o	o
15.	I have been told that I walk, talk, eat or act strange or violent while sleeping.	o	o	o	o	o
16.	I have nightmares.	o	o	o	o	o
17.	For no reason, I awaken suddenly, startled, and feeling afraid.	o	o	o	o	o

Appendix E

Patient Health Questionnaire-9

Patient Health Questionnaire-9

Over the last two weeks, how often have you been bothered by the following problems?

		Not at all	Several days	More than half the days	Nearly every day
1.	Little interest or pleasure in doing things	o	o	o	o
2.	Feeling down, depressed, or hopeless	o	o	o	o
3.	Trouble falling or staying asleep, or sleeping too much	o	o	o	o
4.	Feeling tired or having little energy	o	o	o	o
5.	Poor appetite or overeating	o	o	o	o
6.	Feeling bad about yourself - or that you are a failure or have let yourself or your family down	o	o	o	o
7.	Trouble concentrating on things, such as reading the newspaper or watching television	o	o	o	o
8.	Moving or speaking so slowly that other people have noticed? Or the opposite - being so fidgety or restless that you have been moving around more than usual	o	o	o	o
9.	Thoughts that you would be better off dead or of hurting yourself in some way	o	o	o	o

Appendix F

Generalized Anxiety Disorder -7

Generalized Anxiety Disorder 7

Over the last two weeks, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
1. Feeling nervous, anxious or on edge	o	o	o	o
2. Not being able to stop or control worrying	o	o	o	o
3. Worrying too much about different things	o	o	o	o
4. Trouble relaxing	o	o	o	o
5. Being so restless that it is hard to sit still	o	o	o	o
6. Becoming easily annoyed or irritable	o	o	o	o
7. Feeling afraid as if something awful might happen	o	o	o	o

Appendix G

Psychosis Screening Questionnaire

Psychosis screening questionnaire

			Yes	No	Unsure
1.	PSQ1	Have there ever been times when you felt very happy indeed without a break for days on end?	o	o	o
2.	PSQ_PY1	You indicated yes, that there have been times when you felt very happy indeed without a break for days on end. Did this happen in the last year?	o	o	
3.	PSQ1a	When there have been times when you felt very happy indeed without a break for days on end, was there an obvious reason for this?	o	o	o
4.	PSQ1b	When there have been times when you felt very happy indeed without a break for days on end, did your relatives or friends think it was strange or complain about it?	o	o	o
5.	PSQ2	Have you ever felt that your thoughts were directly interfered with or controlled by some outside force or person?	o	o	o
6.	PSQ_PY2	You indicated yes, that there have been times when you felt that your thoughts were directly interfered with or controlled by some outside force or person. Did this happen in the last year?	o	o	
7.	PSQ2a	When there have been times when you felt that your thoughts were directly interfered with or controlled by some outside force or person, did this come about in a way that many people would find hard to believe, for instance, through telepathy?	o	o	o
8.	PSQ3	Have there been times when you felt that people were against you?	o	o	o
9.	PSQ_PY3	You indicated yes, that there have been times when you felt that people were against you. Did this happen in the last year?	o	o	

10.	PSQ3a	Have there been times when you felt that people were deliberately acting to harm you or your interests?	o	o	o
11.	PSQ3b	Have there been times when you felt that a group of people were plotting to cause you serious harm or injury?	o	o	o
12.	PSQ4	Have there been times when you felt that something strange was going on?	o	o	o
13.	PSQ_PY4	You indicated yes, that there have been times when you felt something strange was going on. Did this happen in the last year?	o	o	
14.	PSQ4a	When there have been times when you felt something strange was going on, did you feel it was so strange that other people would find it very hard to believe?	o	o	o
15.	PSQ5	Have there been times when you heard or saw things that other people couldn’t?	o	o	o
16.	PSQ_PY5	You indicated yes, that there have been times when you heard or saw things that other people couldn't. Did this happen in the last year?	o	o	
17.	PSQ5a	Did you at any time hear voices saying quite a few words or sentences when there was no one around that might account for it?	o	o	o

Appendix H

Sociodemographic characteristics

Age: What is your age?

o 18-24 years

o 25-34 years

o 35-44 years

o 45-54 years

o 55-64 years

o 65 years and over

Gender: What is your Gender?

o Male

o Female

o Transgender

o Prefer not to say

o Other

Sexual orientation: How would you describe your sexual orientation?

o Straight / Heterosexual

o Gay / Lesbian / Homosexual

o Bisexual

o Other

o Prefer not to say

Religion: What is your religious identity?

o Atheist

o Agnostic

o Catholic

o Protestant

o Sunni

o Shia

o Jewish

o Buddhist

o Sikh

o Hindu

o Other

Ethnicity: What is your ethnicity? (from wave 4)

o White British/Irish

o White non-British/Irish

o Indian

o Pakistani

o Chinese

o Afro-Caribbean

o African

o Arab

o Bangladeshi

o Other Asian

o Other ethnic group. Please specify

Relationship status: We'd like to ask you about your current relationship status at this point in time (how you are living now)

o Single - not currently in a committed relationship, but have previously been in a committed relationship

o Single - never been in a committed relationship

o In a committed relationship but not living together

o Cohabiting

o Married

o In a civil partnership

Parental/carer status: Please indicate which of these statements apply to your parental status and living situation (tick multiple if needed).

o I do not have any children

o I have a child/children under 18 years of age, and he/she/they primarily live with me in my household

o I have a child/children under 18 years of age, but he/she/they primarily live elsewhere

o I have a child/children aged 18 years or over, and he/she/they primarily live with me in my household

o I have a child/children aged 18 years or over, but he/she/they primarily live elsewhere

o Someone else's child/children under 18 years of age lives with me in my household

School: Which type of secondary school did you go to? (Tick all that apply)

o State comprehensive school

o State grammar school

o Private day school

o Private boarding school

o I was home-schooled

o Other. Please specify:

o I did not attend secondary school

Appendix I

Neighbourhood characteristics

Neighbourhood belonging: How much do you feel you belong to your immediate neighbourhood?

o Not at all

o Slightly

o Moderately

o Very much

Neighbour Comfort: How comfortable would you be with the following?

Asking a neighbour to keep a set of keys to your home for emergencies

o Very uncomfortable

o Fairly uncomfortable

o Fairly comfortable

o Very comfortable

Asking a neighbour to collect a few shopping essentials for you, if you were ill and at home on your own

o Very uncomfortable

o Fairly uncomfortable

o Fairly comfortable

o Very comfortable

Appendix J

Household finances

Income: Please choose from the following options to indicate your approximate gross (before tax is taken away) household income in 2019. Include income from partners and other family members living with you and all kinds of earnings including salaries and benefits.

o £0 - 15,490 per year

o £15,491 - £25,340 per year

o £25,341 - £38,740 per year

o £38,741 - £57,930 per year

o £57,931 or more per year

Employment: What is your current employment status?

o Employed full-time o Employed part-time

o Self-employed full-time

o Self-employed part-time

o Unemployed, but looking for work

o Unemployed, looking after family or home

o Unemployed, long-term sick or disability

o Been placed on the government 'furlough' scheme

o Retired

o Full-time student

Benefits: Are you currently in receipt of any government benefits (not including child benefits and state pension)?

o Yes

o No

Pay bills: During the last month, would you say you found it difficult to pay your bills?

o Very difficult

o Somewhat difficult

o Not very difficult

o Not at all difficult

Food security: During the last 12 months was there a time when:

Question	Yes	No
1. You were worried you would run out of food because of a lack of money or other resources?	o	o
2. You were unable to eat healthy and nutritious food because of a lack of money or other resources?	o	o
3. You ate only a few kinds of foods because of a lack of money or other resources?	o	o
4. You had to skip a meal because there was not enough money or other resources to get food?	o	o
5. You ate less than you thought you should because of a lack of money or other resources	o	o
6. Your household ran out of food because of a lack of money or other resources?	o	o
7. You were hungry but did not eat because there was not enough money or other resources for food?	o	o
8. You went without eating for a whole day because of a lack of money or other resources?	o	o

Social Rank: Think of a ladder representing where people stand in the United Kingdom. At the top of the ladder are the people who are the best off—those who have the most money, the most education, and the most respected jobs. At the bottom are the people who are the worst off— those who have the least money, least education, and the least respected jobs or no job. The higher up you are on the ladder, the closer you are to the people at the very top; the lower you are, the closer you are to the people at the very bottom.

Rank: Please click the number below to show where you think you stand at this time in your life, relative to the other people in the UK.

o 1

o 2

o 3

o 4

o 5

o 6

o 7

o 8

o 9

o 10

Appendix K

Factor loading table (supplementary)

Table Supplementary 1.

Factor loadings.

Latent	Indicator	β	Std. error	*p*	95% CI	
					Lower	Upper
Sleep disturbance	SDS-CL1	0.53	0.02	< .001	0.49	0.56
	SDS-CL2	0.66	0.02	< .001	0.62	0.69
	SDS-CL3	0.53	0.02	< .001	0.49	0.56
	SDS-CL4	0.83	0.02	< .001	0.80	0.85
	SDS-CL5	0.41	0.02	< .001	0.36	0.46
	SDS-CL6	0.34	0.02	< .001	0.29	0.39
	SDS-CL7	0.58	0.02	< .001	0.55	0.62
	SDS-CL8	0.35	0.02	< .001	0.31	0.40
	SDS-CL9	0.73	0.02	< .001	0.69	0.76
	SDS-CL10	0.67	0.02	< .001	0.62	0.71
	SDS-CL11	0.67	0.02	< .001	0.64	0.71
	SDS-CL12	0.69	0.02	< .001	0.66	0.73
	SDS-CL13	0.73	0.01	< .001	0.70	0.76
	SDS-CL14	0.80	0.02	< .001	0.76	0.83
	SDS-CL15	0.75	0.02	< .001	0.71	0.79
	SDS-CL16	0.67	0.02	< .001	0.64	0.70
	SDS-CL17	0.80	0.01	< .001	0.78	0.83
Mental Health	PHQ1	0.85	0.01	< .001	0.84	0.87
	PHQ2	0.90	0.01	< .001	0.89	0.91
	PHQ3	0.81	0.01	< .001	0.80	0.83
	PHQ4	0.85	0.01	< .001	0.83	0.86
	PHQ5	0.81	0.01	< .001	0.79	0.83

	PHQ6	0.88	0.01	< .001	0.86	0.89
	PHQ7	0.85	0.01	< .001	0.85	0.88
	PHQ8	0.85	0.01	< .001	0.82	0.87
	PHQ9	0.84	0.01	< .001	0.82	0.87
	GAD1	0.94	0.01	< .001	0.93	0.94
	GAD2	0.94	0.01	< .001	0.93	0.95
	GAD3	0.92	0.01	< .001	0.92	0.93
	GAD4	0.93	0.01	< .001	0.92	0.93
	GAD5	0.87	0.01	< .001	0.85	0.88
	GAD6	0.85	0.01	< .001	0.84	0.87
	GAD7	0.91	0.01	< .001	0.90	0.92
	PSQ2 subscale	0.60	0.03	< .001	0.54	0.67
	PSQ3 subscale	0.62	0.02	< .001	0.58	0.66
	PSQ4 subscale	0.57	0.02	< .001	0.53	0.61
	PSQ5 subscale	0.57	0.03	< .001	0.50	0.63
Material hardship	Difficulties paying bills	0.81	0.02	< .001	0.78	0.85
	Food insecurity1	0.92	0.01	< .001	0.87	0.95
	Food insecurity2	0.91	0.02	< .001	0.88	0.93
	Food insecurity3	0.94	0.01	< .001	0.91	0.96
	Food insecurity4	0.93	0.01	< .001	0.91	0.96
	Food insecurity5	0.93	0.01	< .001	0.91	0.96
	Food insecurity6	0.94	0.01	< .001	0.91	0.96
	Food insecurity7	0.96	0.01	< .001	0.94	0.98
	Food insecurity8	0.95	0.01	< .001	0.92	0.97
Support system	Relationship Status	0.38	0.04	< .001	0.30	0.45
	Neighbourhood belonging1	0.71	0.02	< .001	0.66	0.75
	Neighbourhood comfort2	0.89	0.01	< .001	0.87	0.92
	Neighbourhood comfort3	0.89	0.01	< .001	0.87	0.92
	Income	0.67	0.02	< .001	0.62	0.71

Socioeconomic stability	Benefits	0.79	0.04	< .001	0.72	0.86
	Employment	0.39	0.04	< .001	0.32	0.46
	Rank	0.74	0.03	< .001	0.69	0.78

Note. β = standardized beta coefficient; CI = confidence intervals; GAD = Generalized Anxiety Disorder; PHQ = Patient Health Questionnaire; PSQ = Psychosis Screening Questionnaire; SDS-CL = Sleep Disorders Symptom Checklist -17.