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Review

Environmental noise and health in low-middle-income-countries: A systematic review of epidemiological evidence

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ABSTRACT

Evidence of the health impacts from environmental noise has largely been drawn from studies in high-income countries, which has then been used to inform development of noise guidelines. It is unclear whether findings in high-income countries can be readily translated into policy contexts in low-middle-income-countries (LMICs). We conducted this systematic review to summarise noise epidemiological studies in LMICs.

We conducted a literature search of studies in Medline and Web of Science published during 2009–2021, supplemented with specialist journal hand searches. Screening, data extraction, assessment of risk of bias as well as overall quality and strength of evidence were conducted following established guidelines (e.g. Navigation Guide).

58 studies were identified, 53% of which were from India, China and Bulgaria. Most (92%) were cross-sectional studies. 53% of studies assessed noise exposure based on fixed-site measurements using sound level meters and 17% from propagation-based noise models. Mean noise exposure among all studies ranged from 48 to 120 dB (L_{eq}), with over half of the studies (52%) reporting the mean between 60 and 80 dB.

The most studied health outcome was noise annoyance (43% of studies), followed by cardiovascular (17%) and mental health outcomes (17%). Studies generally reported a positive (i.e. adverse) relationship between noise exposure and annoyance. Some limited evidence based on only two studies showing that long-term noise exposure may be associated with higher prevalence of cardiovascular outcomes in adults. Findings on mental health outcomes were inconsistent across the studies. Overall, 4 studies (6%) had "*probably low*", 18 (31%) had "*probably high*" and 36 (62%) had "*high*" risk of bias. Quality of evidence was rated as '*low*' for mental health outcomes and '*very low*' for all other outcomes. Strength of evidence for each outcome was assessed as '*inadequate*', highlighting high-quality epidemiological studies are urgently needed in LMICs to strengthen the evidence base.

1. Introduction

Noise pollution, a consequence of humankind's industrial, commercial, transport-related, and recreational activities, has become a serious public health concern in both developed and developing countries, especially in urban areas (Banerjee, 2012; Argalášová-Sobotová et al., 2013; van Kempen and Babisch, 2012). Exposure to high levels of noise can induce hearing loss and tinnitus due to direct damage to the auditory system. Over the last two decades, growing evidence has also shown that exposure to noise from transportation sources may also result in non-auditory effects on health (Basner et al., 2014; Münzel et al., 2021), such as annoyance, restlessness, disturbance of activities, nervousness, metabolic, and cardiovascular problems (World Health Organization, 2018; World Health Organization, 2011), at levels below those that damage hearing. These cardiovascular and metabolic effects can result from both psychological and physiological distress (Nilsson, 2018; van Kempen and Babisch, 2012; Münzel et al., 2021). Environmental noise may induce acute non-auditory effects directly by activating the autonomic nervous and endocrine systems via sub-cortical interaction, and also indirectly through cortical arousal (Babisch, 2002). Noise-induced sleep loss in the long-term may interfere with the over-production of stress hormones (e.g., cortisol), which could impact

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on health (Nilsson, 2018; van Kempen and Babisch, 2012; Smith et al., 2022). Noise annoyance may be a protective adaption strategy for human being to reducing the actual noise exposure and thereby decreasing aggravating physical stress reactions (Nilsson, 2018; van Kempen and Babisch, 2012).

There have been many reviews conducted to evaluate the epidemiological associations of environmental noise with various health outcomes ranging from cardiovascular to birth outcomes (World Health Organization, 2018; Zare Sakhvidi et al., 2018, International Civil Aviation Organization, 2019; Münzel et al., 2021; Smith et al., 2022; Thompson et al., 2022b; Hegewald et al., 2020b; van Kamp et al., 2020). In 2018, World Health Organization (WHO) published the "*Environmental Noise Guidelines for the European Region*" based on a series of commissioned systematic reviews of studies published up to 2015 (World Health Organization, 2018). Notably, most of these studies were conducted in western and northern European countries. In addition, evidence of the health impacts from aircraft noise was completely drawn from studies in high-income countries (HICs). While these reviews are useful in the discussion of public health policies to control environmental noise, it remains unclear whether such policies, primarily informed by studies in HICs, can be readily translated to low-middle-income-countries (LMICs). This concern is valid given that there exist substantial differences in terms of urban geographical, socio-economical and demographical profiles between LMICs and HICs.

While common in high-income European and North American cities, measuring and modelling environmental noise exposures at city-scale is still lacking in many LMICs, though some studies indicated that exposure levels may be elevated (Clark et al., 2022; Raess et al., 2021; Sieber et al., 2017; Moroe and Mabaso, 2022; Debnath and Singh, 2018; Baloye and Palamuleni, 2015; Okokon et al., 2018). For example, Cai et al., using simulation calculation methods to generate a traffic noise map of Guangzhou, China (2013) found that noise levels were high during the day (L_{day}) (51.9% of the noise exceeded 50 dB; 6.56% of the noise over 70 dB) and night (L_{night}) (52.1% of the noise exceeded 50 dB; 7.61% of the noise over 70 dB) (Cai et al., 2015). Furthermore, an extensive measurement and land use regression (LUR) modelling study in Accra, Ghana found that almost the entire population living in the metropolitan area were exposed to environmental noise above 55 dB of L_{den} and 50 dB of L_{night} (Clark et al., 2022). These studies, while few, may indicate that city dwellers in some LMICs may be exposed to noise levels far exceeding both international and national health-based guidelines, representing a potential risk on the growing burden of non-communicable diseases in LMICs. In the past 10 years, epidemiological evidence from LMICs has slowly emerged to bridge this significant knowledge gap for policy-making. However, a systematic review of such evidence has not been conducted to date.

The aim of this systematic review is to present a timely synthesis of studies on the epidemiological link between environmental noise exposure and health outcomes in LMICs. The specific objectives of this review are to summarise (a) the relationships between short- and long-term environmental noise exposure and mental or physical health outcomes; (b) future research directions and policy perspectives in the context of LMICs. Occupational noise is out-of-scope in this review given its unique contexts in noise characteristics, exposure timeframe, exposed populations, health responses and policy regulations as compared to other forms of environmental noise. In fact, the WHO and the International Labour Organization (ILO) have recently reviewed occupational noise and health from studies in both HICs and LMICs (Teixeira et al., 2021).

2. Methods

We followed the Navigation Guide methodology and criteria in conducting and reporting this review (Johnson et al., 2016). We defined "LMICs" using the World Bank 2021 list (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups, accessed Oct 11, 2022). Studies from countries and regions by Gross National Income nominal (GNI) per capita classified in low-income economies ($1045 or less), lower-middle-income economies ($1046 – $4095) and upper-middle-income economies ($4096 and $12,695) were included in this review (See Supplementary 1 for list of countries).

2.1. Identification and selections of studies

We conducted a search for epidemiological studies in LMICs focusing on environmental noise (including road traffic noise, railway noise, aircraft noise, community noise, wind turbine noise, etc.) as exposure and its effects on health (including annoyance, cardiovascular disease, mental health, etc.). Medline and Web of Science databases were used to originally search published articles from January 1, 2009 and November 4, 2019, which was later updated to November 10, 2021 (date of the final search). We focused on studies in the last decade or so as to our best knowledge this was the period when the evidence from LMICs started to emerge. Detailed search strings for each electronic database are available in Supplementary 2. Additional efforts were made to search the bibliography in review papers and conference proceedings, as well as through our own reference libraries.

Study selection criteria are given in Table 1, following the PECO

Table 1
Eligibility criteria to screen studies for the review.

Components	Inclusion criteria	Exclusion criteria
Study type	Epidemiologic studies were included, e.g. ecological studies, cross-sectional studies, prospective and retrospective cohort studies, case-control studies and observational or experimental studies of people exposed to environmental noise.	In-vitro, toxicological, animal, or controlled exposure studies were excluded.
Population	Members of the general population as well as specific segments of the population particularly at risk, such as children or vulnerable groups. Eligible study participants are those exposed to noise from home setting, traffic, and leisure activities.	Studies participants exposed to occupational or laboratory-based noise were excluded.
Study location	Eligible study conducted in LMICs Country/regions, using world bank list https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups).	Studies took place in other countries or area were excluded.
Exposure	Both short- and long-term environmental noise exposure from road, rail, aircraft, transport, industrial, wind turbine, construction and communities. Noise exposure levels was calculated and expressed in decibel (dB) values, or on the basis of subjective ratings, that aimed to be representative of the individual exposure of the study participants.	Studies participants exposed to occupational or laboratory-based noise were excluded
Outcome	Assessment of several health outcomes, including but not limited to, sleep, annoyance, cognitive impairment, quality of life, cardiovascular disease (e.g., ischemic heart disease, hypertension, stroke), metabolic disease (e.g., obesity, diabetes mellitus).	Health outcomes relating to underlying biological mechanisms, e.g., epigenetics, metabolomics, methylation was excluded.

(Population, Exposure, Comparator and Outcome) approach. The lead author (YC) screened titles and abstracts against the eligibility criteria at the first stage and read full texts of potentially eligible records at the second stage. During the screening process, if there was question on eligibility of any study, this was resolved through mutual discussion with all authors.

2.2. Data extraction and preparation

A pre-designed standardized data extraction form in Microsoft Excel was used to collect the following variables from each included study, conducted by the lead author (YC): first author, publication year, study design, study region, study population, population characteristics (age and sex where available), exposure assessment (type), statistical analysis, confounders, investigated health outcomes, ascertainment of outcome, key findings, and overall risk of bias (ROB).

There are three publications reporting on the same annoyance outcomes based on the same population at the Hanoi Noi Bai International Airport, Vietnam (Nguyen et al., 2020; Nguyen et al., 2018; Morinaga et al., 2020). We only chose one of these publications (Nguyen et al., 2020) with more waves of noise exposure data over the follow-up period from 2014 to 2018.

2.3. Risk of bias evaluation in individual studies

We followed the protocol for ROB assessment of individual studies developed jointly by the WHO and ILO (Teixeira et al., 2019), which was largely adapted from the Navigation Guide. The nine ROB domains are: (1) source population representation; (2) exposure assessment; (3) outcome assessment; (4) confounding; (5) blinding; (6) incomplete outcome data; (7) selective outcome reporting; (8) conflict of interest and (9) other sources of bias. For each of these domains, risk of bias was assigned to one of the five categories: *low, probably low, probably high, high, and not applicable*. For criterion (4) confounding, we specified tier 1 (important) confounders as: age, sex, and socioeconomic status (SES) and tier 2 (other potentially relevant) confounder as tobacco smoking. We used the detailed instructions from the WHO/ILO protocol to assign rating to each domain for each study (Supplementary 3). Two authors (YC + YSC) reviewed independently the full text of all included papers (and additionally SC reviewed for exposure assessment sections) guided by the aforementioned instructions. Any disagreements were discussed and collectively decided and resolved. The overall ROB at study level was decided by the worst rating in any bias domain.

2.4. Quality and strength of evidence

The overall quality and strength of evidence for each health outcome was evaluated according to the Navigation Guide as detailed in (Johnson et al., 2016). The lead author (YC) conducted an initial evaluation of quality and strength, and this initial evaluation was checked and revised by all authors following discussions. In brief, all studies were assumed to be of a moderate quality and subsequently downgraded or upgraded according to set criteria (Supplementary 4); the overall quality of evidence for each health outcome was then used in part to inform the overall strength of evidence (Supplementary 5).

3. Results

3.1. Search results

The selection process of the literature is shown in Fig. 1. The literature search yielded 516 references. After screening the titles and abstracts, we excluded 454 records. We went through 62 records in full-text assessment for eligibility listed in Table 1 where a further 23 records were excluded, details of papers excluded can be found in Supplementary 6. A further 19 eligible studies were identified from existing reviews (N = 10), and our own references database (N = 9) which could not be found in Medline or Web of Science. Overall, 58 studies meeting the eligibility criteria were included in the review.

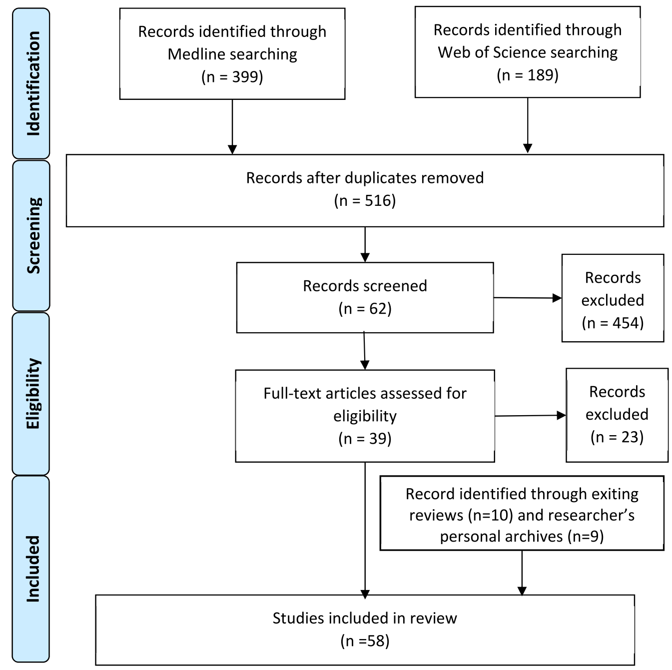

Fig. 1. The selection process of the literature.

3.2. Description of included studies

The study characteristics of the 58 studies identified is shown in Fig. 2. All the studies were undertaken in 14 LMICs across Asia, Europe, Africa and the Americas. Most of the studies were conducted in India (N = 13, 22.0%), followed by China (N = 10, 17%) and Bulgaria (N = 8, 14%).

The study designs consisted of cross-sectional (N = 54, 92%), cohort (N = 3), ecological (N = 1) and case-crossover (N = 1) studies. The year with highest number of published studies was 2021 (N = 7) and the lowest number of published studies (N = 3) were in 2011, 2012 and 2017.

In terms of studied health outcomes, twenty-six (43%) studies focussed on annoyance or perception, ten (17%) studies on cardiovascular diseases, ten studies (17%) on mental health outcomes, four on quality of sleep (7%), three (7%) on cognitive outcomes, two on hearing loss/deafness, one on Type 2 diabetes (T2DM), one on self-reported body mass index (BMI), and one on health-related quality of life (HRQOL).

3.3. Exposure assessment techniques

The exposure assessment techniques present in the reviewed studies are shown in Fig. 3, and detailed information about the exposure assessment methods used for each study are summarised in Supplementary 7. Thirty-one (53%) studies assessed noise exposure based on measurements with fixed-site sound level meters (SLM), ten studies (17%) used propagation-based model(s), five studies with self-reported subjective rating, four with personal monitoring using SLMs, three used both fixed -site SLM measurement and propagation-based model, three used land used regression (LUR) models, and two assigned exposures by a proxy variable (i.e. living near a major road).

The mean level of noise exposure among all the reviewed studies ranged from 48.0 dB to 120.1 dB dB (L_{eq}), with over half of studies (N = 30, 51.7%) reporting mean noise levels of 60–80 dB in the study areas.

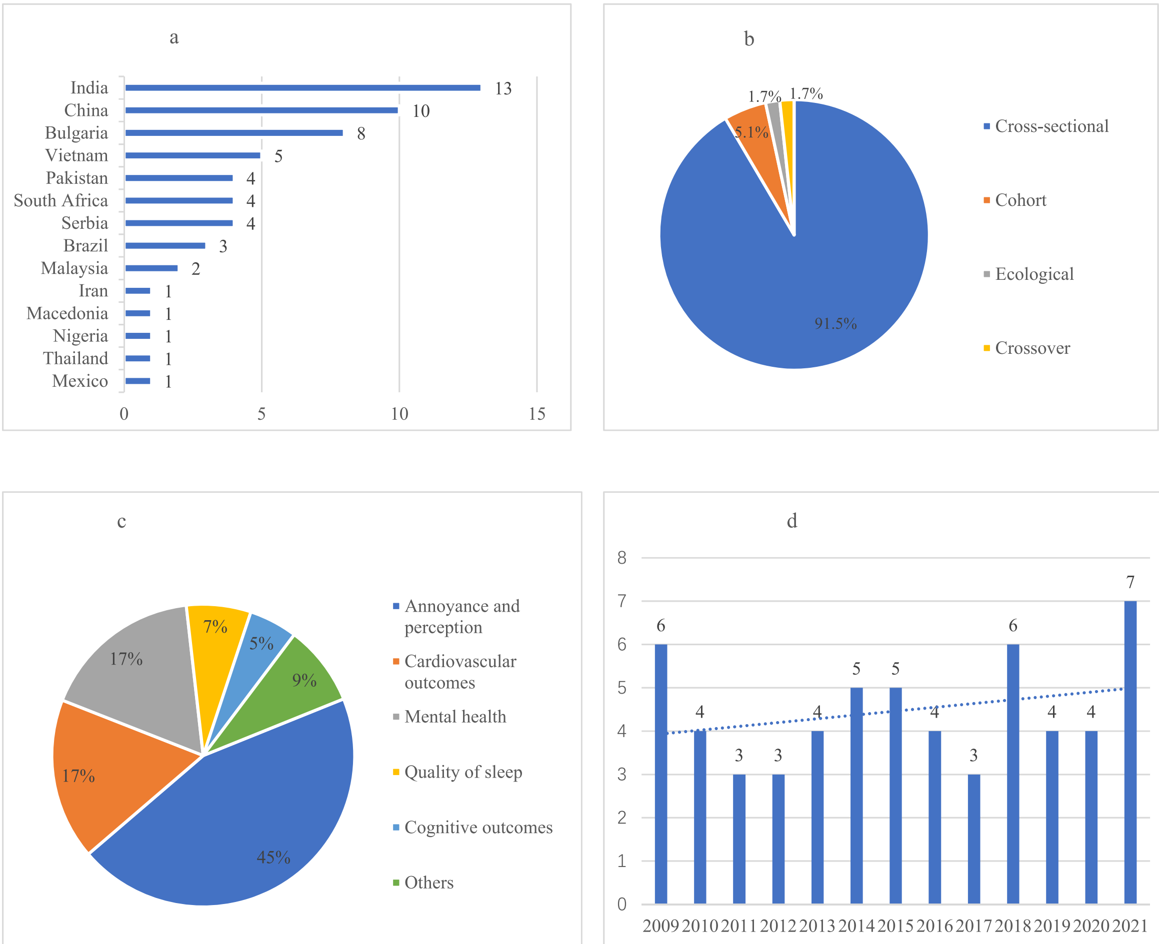

Fig. 2. Study characteristics (country, study design, health outcome and number of paper per year from 2009 to 21).

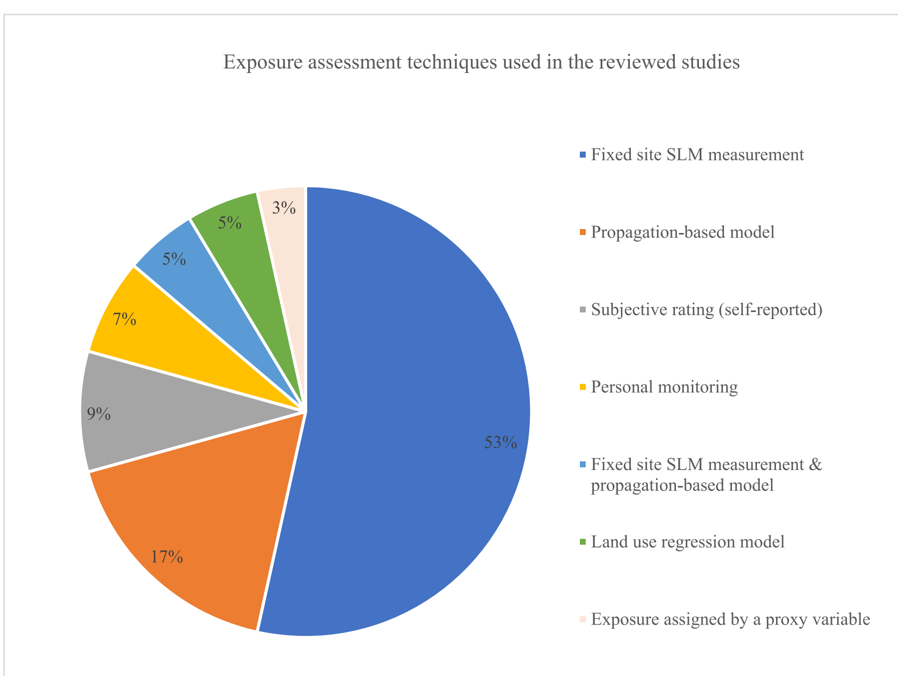

Fig. 3. Exposure assessment techniques used in the reviewed studies.

For bias due to noise exposure assessment, many of the measurement-based studies (N = 29 out of 31) were rated as "*high*" or "*probably high*" risk because measurement protocols were not robust and/or they were deemed to lack the ability to capture sufficient spatial and/or temporal variations in study participant exposures. Conversely, the four personal exposure studies from Beijing, China were rated as "*low*" ROB for exposure as they were able to capture both spatial and temporal variations in exposure and the time-activity patterns of each study participant, which can influence exposure distributions. Eight out of 10 studies based on propagation-based modelling were rated a "*high*" or "*probably high*" ROB often because of limitations in, or lacking information on, input data (e.g., inclusion; spatial/temporal resolutions) and/or a lack of model validation (i.e., with local measurements). The studies characterizing exposures based on subjective responses and by proxy had ratings of "*high*" ROB due to the risk of exposure misclassification from recall bias, subjectivity, and/or lacking in accuracy, and the three LUR studies were rated as "*probably high*"/"*high*" ROB.

3.4. Risk of bias assessment

In each of the nine ROB domains, for all studies, the majority of ratings were "*high*" or "*probably high*" (Table 2). The individual bias assessment categories and rationale given for each study are included in Supplementary 8 (Table 8.1, 8.2, 8.3, 8.4, 8.5, and 8.6). There was the most potential for bias regarding exposure assessment ("*probably high*"/"*high*" ratings: N = 49), confounding ("*probably high*"/"*high*" ratings: N = 38) and population representative ("*probably high*"/"*high*" ratings: N = 36). Based on the worst rating in any bias domains in each study, there were 36 (62.1%) studies with "*high*" ROB, 18 (31.0%) studies with "*probably high*" ROB, and 4 (6.9%) studies with "*probably low*" ROB. No studies were rated as having '*low*' ROB. Among those 18 studies rated "*probably high*", eight studies included a "*probably high*" rating in less than three domains.

For each health outcome, we conducted a narrative synthesis of studies for which the overall ROB were rated as "*probably low*", or "*probably high*" with less than three "*probably high*" rated across ROB domains.

3.5. Health outcomes

3.5.1. Annoyance and perception

This review identified 26 studies of associations of environmental noise with annoyance (One cohort study (Seabi, 2013) and 25 cross-sectional studies (Banerjee, 2013;Phan et al., 2010; Liu et al., 2017; Sieber et al., 2018; Wu et al., 2019; Nazneen et al., 2020Zamorano-Gonzalez et al., 2021;Agarwal and Swami, 2010; Goswami, 2009; Song et al., 2016; Nandanwar et al., 2009; Agarwal and Swami, 2011; Onchang and Hawker, 2018; Dias et al., 2021; Paiva et al., 2019; Banerjee et al., 2009; Daruis et al., 2014; Firdaus and Ahmad, 2010; Guoqing et al., 2012; Paunović et al., 2014; Ristovska et al., 2009; Trieu et al., 2021; Nguyen et al., 2020; Gjestland et al., 2015; Nguyen et al., 2011), see Supplementary 9, Table 9.1). The studies were from India (N = 7), Vietnam (N = 5), China (N = 4), South Africa (N = 2), Brazil (N = 2), and other countries. Risk of bias was rated as "*probably high*" for four of these (Paunović et al., 2014; Song et al., 2016; Nguyen et al., 2020; Trieu et al., 2021) and "*high*" for the remaining 22 studies. There was the most potential for bias regarding confounding ("*high*" ratings: N = 19) because most studies only conducted simple correlation analysis (N = 10) without adjustment of some potential confounders.

Among those four studies with "*probably high*" ROB, three defined participants who chose 8, 9, or 10 out of the 11-point numerical (0–10) scale as "highly annoyed" following the International Commission on Biological Effects of Noise (ICBEN) method (Paunović et al., 2014; Nguyen et al., 2020; Trieu et al., 2021) and the other one defined participants who answered being "rather annoyed" and "extremely annoyed" as 'highly annoyed" used a five-point verbal rating scales (Song et al., 2016). All of them used logistic regression models. Noise was positively associated with likelihood of being highly annoyed, reaching statistical significance for all but one study (Trieu et al., 2021). Two studies focussed on aircraft noise in Ho Chi Minh City, Vietnam found for 1 dB change in L_{den}, noise annoyance increased by 29.7% (95% CI: 24.8%, 34.9%) (Nguyen et al., 2020) and 25% (95% CI: 20%, 31%) respectively (Trieu et al., 2021). One study, focussed on road traffic noise in Belgrade, Serbia found noise annoyance increase by 3% (Odds Ratio (OR): 1.03, 95% CI: 1.01, 1.05) per 1 dB (L_{eq}) increased in daytime noise level (Paunović et al., 2014). Another study in Yueyang, China found the odds of being highly annoyed increased by 20.8% (95% CI: 6%, 38%) for per 1 dB(A) increase of wind turbine noise in L_{Aeq} (Song et al., 2016).

3.5.2. Cardiovascular diseases (CVDs)

This review identified 10 studies of associations of environmental noise on CVDs (8 cross-sectional (Gilani and Mir, 2021; Lepore et al., 2010; Paunovic et al., 2013; Banerjee et al., 2014a; Banerjee et al., 2014b; Dzhambov et al., 2016; Farooqi et al., 2021; Hamid et al., 2019), one case-crossover (Huang et al., 2013) and one ecological (Roca--Barcelo et al., 2021). The detailed data extraction for these studies is shown in Supplementary 9, Table 9.2.

Among these, overall ROB for one study was rated as "*probably low*" (Huang et al., 2013) and three studies were rated as "*probably high*" with less than three "*probably high*" ROB domains (Paunovic et al., 2013; Gilani and Mir, 2021; Roca-Barcelo et al., 2021). There was the most potential for bias regarding exposure assessment ("*high*" ratings: N = 4; "*probably high*" ratings: N = 4). Two studies assessed noise exposure based on propagation-based model (Gilani and Mir, 2021; Roca-Barcelo et al., 2021), one based on fixed-site SLM measurement (Paunovic et al., 2013), and the other used personal SLM monitoring (Huang et al., 2013). In terms of statistical method, two studies used logistic regression models (Gilani and Mir, 2021; Roca-Barcelo et al., 2021)and two used mixed linear models (Paunovic et al., 2013;Huang et al., 2013). Different cardiovascular outcomes were investigated among those four studies, including heart rate variability (HRV) (Huang et al., 2013), coronary artery disease (CAD) (Gilani and Mir, 2021), cardiovascular mortality in adults (Roca-Barcelo et al., 2021), and blood pressure (BP) in children (Paunovic et al., 2013).

In the case-crossover study in Beijing, China, 40 young healthy adults were asked to stay for 2 h in a traffic centre and a park in another exposure scenario without moving for HRV measurement duration (Huang et al., 2013). This study found that for 1 dB(A) (L_{Aeq}) increase in noise, HRV indices significantly changed. Decrease of the percentage of differences between adjacent normal RR intervals that are larger than 50 ms (pNN50) and high frequency (HF) and increase of low-to-high frequency power ratio (LFHFR) with changes of −3.10% (95% CI: −4.56%, −1.62%), −1.71% (95% CI: −3.03%, −0.36%), and 2.49% (95% CI, 1.14%, 3.85%), respectively (Huang et al., 2013). A study in India reported that residents living in noisy areas had a 2.25 (95% CI: 1.38, 3.67) times higher risk of CAD for 5 dB(A) increment in L_{den} (Gilani and Mir, 2021). One ecological study around Congonhas airport, Brazil assessed effects of aircraft noise exposure on cardiovascular mortality (Roca-Barcelo et al., 2021). It was found that areas exposed to the highest levels of noise (>65 dB) showed a non-statistically significant relative risk (RR) for all CVD and coronary heart disease (CHD) mortality of 1.06 (95% CI: 0.94, 1.20) and 1.11 (95% CI: 0.96, 1.27) respectively, compared to those areas exposed to reference noise levels (≤50 dB) (Roca-Barcelo et al., 2021). One study in Belgrade, Serbia of 1113 children aged 7–11 years, measured noise level in schools (in the day time) and in all 115 streets where children lived (in day and night time) (Paunovic et al., 2013). This study also counted the number of vehicles and assessed the presence of public transport by matching children's home and school addresses with public transport maps (Paunovic et al., 2013). Systolic blood pressure (SBP) was not significantly associated with increases of noise levels, but children attending

Table 2
Risk of bias assessment.

Study	Source population representation	Exposure assessment	Outcome assessment	Confounding	Blinding	Incomplete outcome data	Selective outcome reporting	Conflict of interest	Other sources of bias	Overall risk of bias
Annoyance										
Paunović et al., 2014	PH	PH	PL	PL	L	L	L	N/A	PL	PH
Song et al., 2016	L	PL	PL	PH	L	L	L	L	PL	PH
Nguyen et al., 2020	PL	PH	PL	PH	L	L	L	L	PL	PH
Trieu et al., 2021	PL	PH	PL	PH	L	L	L	L	PL	PH
Agarwal and Swami, 2010	PH	H	H	H	L	PH	L	N/A	L	H
Goswami, 2009	H	H	H	H	L	PH	L	N/A	L	H
Nandanwar et al., 2009	H	H	H	H	L	PH	L	N/A	L	H
Ristovska et al., 2009	PH	H	PL	H	L	L	L	N/A	L	H
Banerjee et al., 2009	PH	H	H	H	L	PH	L	N/A	L	H
Phan et al., 2010	PL	H	PL	H	L	L	L	N/A	L	H
Firdaus 2010	H	H	H	H	L	L	L	L	L	H
Agarwal 2011	PL	H	H	H	L	PH	L	N/A	L	H
Nguyen et al., 2011	PL	H	PL	H	L	L	L	N/A	L	H
Guoqing et al., 2012	PH	H	PL	H	L	L	L	N/A	L	H
Seabi, 2013	PL	PH	PL	H	L	L	L	L	L	H
Banerjee, 2013	PH	H	H	PH	L	L	L	N/A	L	H
Daruis et al., 2014	PH	H	H	H	L	PH	L	N/A	L	H
Gjestland et al., 2015	PL	H	PL	H	L	L	L	N/A	L	H
Liu et al., 2017	PL	PL	PL	H	L	L	L	N/A	L	H
Sieber et al., 2018	L	H	PL	H	L	L	L	L	L	H
Onchang 2018	PH	PH	PL	H	L	L	L	L	L	H
Wu et al., 2019	PL	H	H	H	L	L	L	N/A	L	H
Paiva et al., 2019	PH	PL	H	PL	L	L	L	N/A	L	H
Nazneen et al., 2020	PH	H	H	PL	L	L	L	L	L	H
Zamorano-Gonzalez et al., 2021	PH	H	H	H	L	L	L	N/A	L	H
Dias et al., 2021	PL	H	H	H	L	L	L	N/A	PL	H
Cardiovascular outcomes										
Huang et al., 2013	PL	L	L	L	L	L	L	L	PL	PL
Paunovic et al., 2013	PH	PL	L	PL	L	L	L	L	PL	PH
Banerjee et al., 2014a	PH	PH	PH	PL	L	L	L	L	PL	PH
Banerjee et al., 2014b	PH	PH	PH	PL	L	L	L	L	PL	PH
Dzhambov et al., 2016b	PH	PH	PH	L	L	L	L	L	PH	PH
Gilani and Mir, 2021	PL	PL	PH	PL	L	L	L	L	PL	PH
Roca-Barcelo et al., 2021	L	PH	L	PL	L	L	L	L	L	PH
Lepore et al., 2010	PH	H	L	PH	L	L	L	L	PH	H
Hamid et al., 2019	H	H	PH	H	L	PH	L	L	H	H
Farooqi et al., 2021	H	H	PH	H	L	PH	L	L	H	H
Mental health										
Ma et al., 2020	L	L	PL	L	L	L	L	L	PL	PL
Tao et al., 2020	L	L	PL	L	L	L	L	L	PL	PL
Tao et al., 2021	L	L	PL	L	L	L	L	L	PL	PL
Dzhambov et al., 2017	PH	PH	PL	L	L	L	L	L	PH	PH
Dzhambov et al., 2018a	PH	PH	PL	L	L	L	L	L	PH	PH
Dzhambov et al., 2018b	PH	PH	PL	L	L	L	L	L	PH	PH
Dzhambov et al., 2019	PH	PH	PL	L	L	L	L	L	PH	PH
Dzhambov 2014	PH	H	PL	H	L	L	L	N/A	PH	H
Masoudzadeh et al., 2017	PH	H	PL	H	L	L	L	N/A	L	H
Ma et al., 2018	L	H	PL	L	L	L	L	L	PL	H
Quality of sleep										
Stošić et al., 2009	PH	H	PH	H	L	L	L	N/A	L	H
Goswami et al., 2011	H	H	H	H	L	PH	PH	N/A	L	H
Han et al., 2015	PL	H	PH	H	L	L	L	L	L	H
Ravindra et al., 2016	PH	PH	PH	H	L	L	L	N/A	L	H
Cognitive outcomes										
Belojevic et al., 2012	PH	PH	PL	PH	L	L	L	L	L	PH
Seabi et al., 2015	PL	PH	PL	PH	L	L	L	N/A	L	PH
Seabi et al., 2012	PL	PH	PL	H	L	L	L	N/A	L	H
Other outcomes										
Dzhambov 2015	PH	PH	PH	L	L	L	L	L	PH	PH
Dzhambov et al., 2016a	PH	PH	PH	L	L	L	L	L	PH	PH
Ana et al., 2009	PH	PH	PH	H	L	PH	L	L	L	H
Siddiqui et al., 2015	H	H	PH	H	L	PH	L	L	L	H
Ali et al., 2018	PH	H	PH	H	L	L	L	L	L	H

school with public transport nearby had 1.3 mmHg (95% CI: 0.07, 2.58) higher SBP compared to those without public transport nearby (Paunovic et al., 2013). Despite the heterogeneity of the outcomes investigated, all four studies found a negative effect of noise on cardiovascular outcomes.

3.5.3. Mental health outcomes

This review identified 10 studies of associations of environmental noise on mental health outcomes (Tao et al., 2021; Dzhambov et al., 2017; Masoudzadeh et al., 2017; Dzhambov and Dimitrova, 2014; Dzhambov et al., 2018b; Dzhambov et al., 2018a; Dzhambov et al., 2019; Ma et al., 2018; Ma et al., 2020; Tao et al., 2020), all of them were based on a cross-sectional design. The detailed data extraction for these studies is shown in Supplementary 9, Table 9.3. Overall ROB was rated as "*probably low*" for three of these (Ma et al., 2020; Tao et al., 2020; Tao et al., 2021), "*probably high*" (Dzhambov et al., 2017; Dzhambov et al., 2018b; Dzhambov et al., 2018a; Dzhambov et al., 2019) for four and "*high*" for the remaining three (Masoudzadeh et al., 2017; Dzhambov and Dimitrova, 2014; Ma et al., 2018).

All three studies with overall "*probably low*" ROB are from Beijing, China and all assessed noise exposure based on personal SLM monitoring. Two studies assessed psychologic stress level by Geographic Ecological Momentary Assessment (GEMA) which combined individual's GPS trajectories and psychological stress in real-time as delivered by GPS-equipped smartphone (Tao et al., 2020; Tao et al., 2021). Momentary stress levels were measured by asking participants "*How much stress do you experience now*" on a 4-point scale (1 = little, 2 = slight, 3 = moderate, and 4 = serious). Both studies reported that noise was associated with increased momentary stress levels. One study found that with each additional increase of one standard deviation (SD) of measured noise level (12.0 dB L_{Aeq}), the momentary stress level increased by 7.2% (95% CI: 5.8%, 8.6%) (Tao et al., 2020). The other study found that per inter-quartile increase in noise (L_{Aeq}), it was positively associated with momentary stress levels although not statistically significant (OR = 1.15; 95% CI: 0.95, 1.56, IQR = 7.98 dB) (Tao et al., 2021). One study assessed mental health by asking the question: "*In general, how would you evaluate your mental health status over the past few weeks*?" The responses were quantified on a 5-point Likert scale ranging from 1 (very poor) to 5 (very good). This study found that noise was negatively associated with residents' self-reported mental health (Ma et al., 2020). Individual-level noise exposure based on their space-time behaviours over a 24-h period ($L_{eq,24h}$) was significantly associated with residents' self-reported mental health, in both weekday (−0.93, 95% CI: −1.85, −0.02) and weekend models (−1.89, 95% CI: −3.39, −0.38) (Ma et al., 2020).

3.5.4. Quality of sleep

This review identified only four studies of associations of environmental noise on quality of sleep in LMICs. The detailed data extraction for these studies is shown in Supplementary 9, Table 9.4. The studies were from India (N = 2), China (N = 1) and Serbia (N = 1), all of them were based on a cross-sectional design. All these studies reported adverse effects of noise on sleep quality (Stošić et al., 2009; Han et al., 2015; Ravindra et al., 2016; Goswami et al., 2011), however, all of them were rated as having overall "*high*" ROB. There was the most potential for bias regarding confounding ("*high*" ratings: N = 4) because all studies conducted simple correlation analysis. In terms of definition of sleep quality, one studied assessed sleep quality by Pittsburgh Sleep Quality Index (PSQI) (Han et al., 2015), one used questionnaire constructed following the ICBEN method (Ravindra et al., 2016), one used 5-point Likert scale (Stošić et al., 2009) and one did not provide detail on how sleep quality was assessed (Goswami et al., 2011).

3.5.5. Cognitive outcomes

This review identified three studies of associations of environmental noise on cognitive outcomes (Seabi et al., 2015; Belojevic et al., 2012; Seabi et al., 2012). The detailed data extraction for these studies is shown in Supplementary 9, Table 9.5. One study was rated as "*high*" overall ROB (Seabi et al., 2012), the other two were rated as "*probably high*" (Seabi et al., 2015; Belojevic et al., 2012), of which one study had less than three "*probably high*" rated across ROB domains (Seabi et al., 2015). This particular study was conducted by the Road and Aircraft Noise Exposure on Children's Cognition and Health (RANCH-SA) longitudinal cohort study, which investigated the impact of environmental noise, specifically aircraft noise, on primary school learners' reading comprehension. Noise exposure was assessed by fixed-site SLM measurement and reading comprehensive assessed with Suffolk Reading Scale Level 2.22. This study did not observe significant associations of noise effects with reading comprehension (Seabi et al., 2015). The reading comprehension mean score of the low noise group (L_{eq}: 50.5; Mean ± SD: 43.52 ± 12.4) did not differ significantly (P > 0.16) from that of the high noise group (L_{eq}: 55.2, Mean ± SD: 35.41 ± 15.7) in 2010. There was also no statistically significant difference (P > 0.06) between the high noise group (Mean ± SD: 58.78 ± 17.2) and low noise group (Mean ± SD: 46.29 ± 16.8) on reading comprehension in 2011.

3.5.6. Other outcomes

There were five studies investigating other health outcomes including hearing loss (N = 2) (Siddiqui et al., 2015; Ana et al., 2009), health-related quality of life (HRQOL) (Ali et al., 2018), T2DM (Dzhambov and Dimitrova, 2016), and BMI (Dzhambov and Dimitrova, 2015). The detailed data extraction for these studies is shown in Supplementary 9, Table 9.6. All of them were based on cross-sectional study design. Overall ROB was rated as "*probably high*" for two (Dzhambov and Dimitrova, 2016; Dzhambov and Dimitrova, 2015) (with more than three "probably high" across ROB domains) and "*high*" ROB for the remaining three studies.

3.6. Overall quality & strength of evidence

We evaluated the overall quality of evidence separately for each health outcome using the eight criteria in the Navigation Guide. We assessed the evidence related to mental health to be of "*low*" quality; the quality of evidence for all other examined health outcomes to be "*Very low*". The most common reasons for downgrading the quality of evidence were due to the "risk of bias" and "imprecision" criteria for differing risk estimates and wide confidence intervals (see Table 3, Supplementary 10 and 11 for details). Similarly, we rated the overall strength of evidence of harmfulness to be "*Inadequate*" for all health outcomes.

4. Discussion

4.1. Summary of findings

To our knowledge, this is the first review on the health impacts of environmental noise in LMICs. Overall, we identified 58 studies published between 2009 and 2021 that met the inclusion criteria. Among the studies identified, the most frequently investigated outcomes included annoyance, cardiovascular health and mental health. Most of these studies were of cross-sectional design, conducted with relatively small sample sizesand assessments of exposure were often deemed to have a high risk of exposure misclassification. Collectively, most studies were deemed to have an overall high risk of bias. This has largely limited our ability to draw conclusions from the current evidence base.

Nonetheless, several lines of evidence appear to be consistent with that reported from previous studies, conducted in mostly HICs. For example, studies in LMICs generally have reported a positive association between noise exposure and annoyance, with higher levels of noise contributing to a higher proportion of the population being highly annoyed. Among the extremely limited number of studies on CVD outcomes, it was reported that short-term noise exposure may slightly increase blood pressure in children in Serbia and long-term noise exposure

Table 3
A summary of the quality and strength assessments.

Health outcome	Quality criteria								Overall quality	Strength
	Risk of bias	Indirectness	Inconsistency	Imprecision	Publication bias	Large magnitude of effect	Dose-response	Residual Confounding Increases Confidence		
Annoyance and perception	−2	0	0	−1	0	0	0	0	Very low	Inadequate evidence of harmfulness
Cardiovascular outcomes	−2	0	−1	−1	0	0	0	0	Very low	Inadequate evidence of harmfulness
Mental health	−1	0	0	−1	0	0	0	0	Low	Inadequate evidence of harmfulness
Quality of sleep	−2	0	0	−1	0	0	0	0	Very low	Inadequate evidence of harmfulness
Cognitive outcomes	−2	−1	−1	−1	0	0	0	0	Very low	Inadequate evidence of harmfulness
Others	−2	0	0	−1	0	0	0	0	Very low	Inadequate evidence of harmfulness

was linked to higher prevalence of hypertension or CAD in adults in India. Studies on all other outcomes remain limited, which precluded a meaningful synthesis of the findings.

4.2. Comparison with previous reviews and the WHO commissioned reviews

There are two reviews for LMICs which summarised evidence at the country level, including a 2012 meta-analysis of residential road traffic noise and annoyance in an Indian sub-population (Banerjee, 2012) and a 2011 narrative review on environmental noise effects on cardiovascular outcomes in Serbia (Belojevic et al., 2011). The Serbian review included five studies all published pre 2009 (Belojevic et al., 2011). The Indian review summarised the evidence from 1991 to 2009 and found long-term noise exposure to road traffic noise may be associated with an increased risk of annoyance (Banerjee, 2012). Our review provides an important update on the latest progress made in the research area of noise and health in a much wider LMICs context.

For annoyance, the systematic review supporting the 2018 WHO Environmental Noise Guidelines for the European Region (the 2018 WHO review hereafter) identified 62 studies mostly from HICs (Guski et al., 2017). The review reported a correlation between road traffic noise levels and annoyance raw scores ($r = 0.325$; $p < 0.001$; from 21 studies) and OR for % highly annoyed -increase per 10 dB increase of noise level (50 dB vs. 60 dB L_{den}) (summary OR = 2.74, 95% CI: 1.88, 3.99; $p < 0.001$; from 12 studies). Our findings from the four studies with "*probably high*" ROB from Vietnam, Serbia, and China are largely consistent with those from the WHO review, with the percentage of populations being highly annoyed increasing with higher levels of noise.

For hypertension, the 2018 WHO review reported a relative risk (RR) of 1.05 (95% CI: 1.02, 1.08) per 10 dB (L_{den}) increase of road traffic noise (Van Kempen et al., 2018). Direct comparisons cannot be made between our review and the WHO review because only one study with an overall ROB rating of "*probably high*" measuring BP levels in children and one study with an overall ROB rating of "*probably high*" using self-reported hypertension were available in LMICs.

For mental health, there were no quantitative estimates from either the 2018 WHO review (Clark and Paunovic, 2018b) or from a more recent updated review (Clark et al., 2020a). Both reviews concluded that there was low-quality evidence for a harmful effect of road traffic noise on measures of depression and anxiety. One recent meta-analysis of five aircraft noise studies found that depression risk increased significantly by 12% per 10 dB L_{den} (RR: 1.12, 95% CI: 1.02, 1.23). In contrast, the meta-analyses of road (11 studies) and railway traffic noise (3 studies) indicated 2–3% (not statistically significant) increases in depression risk per 10 dB L_{den} (Hegewald et al., 2020a). Our findings from the three studies with overall "*probably low*" ROB from China are consistent with those from the previous reviews that there is low-quality evidence for a harmful effect of road traffic noise on self-reported mental health or stress and rated the overall strength of evidence of harmfulness to be "*Inadequate*".

For quality of sleep, the 2018 WHO review reported an OR for the percent highly sleep disturbed for a 10 dB increase in L_{night} for aircraft (1.94; 95% CI 1.61, 2.3), road (2.13; 95% CI 1.82, 2.48), and rail (3.06; 95% CI 2.38, 3.93) noise (Basner and McGuire, 2018). Our review was not able to draw any conclusions in LMICs based on the four identified cross-sectional studies, which were rated as having *high* overall ROB.

For cognition, the 2018 WHO review did not provide a quantitative estimate but indicated evidence of moderate quality for an association between aircraft noise and reading comprehension: of the 14 studies reviewed, 10 demonstrated a statistically significant association between higher aircraft noise exposure and poorer reading comprehension (Clark and Paunovic, 2018a). An updated review found moderate quality evidence for an association between aircraft noise and reading and language in children, and moderate quality evidence against an association between aircraft noise and executive functioning in children (Thompson et al., 2022a). The present review only found one study from South Africa but with a "*probably high*" overall ROB, in which a significant association was not found with aircraft noise on the reading comprehension.

4.3. Exposure assessment

The reviewed noise epidemiological studies from LMICs largely focused on noise from road-traffic sources, while a few studies focussed on noise from aircraft or noise in community settings, one on construction noise, and one study focused on noise from wind turbines. No studies considered leisure noise. As well, all studies characterized average noise levels rather than noise frequency or peak levels.

The majority of the reviewed studies from LMICs used measurement-based approaches to characterize exposures. Within large-scale epidemiological studies in Europe (Khan et al., 2018), however, it has been common to derive exposures from propagation-based noise modelling, which is based on the mathematical description of source emissions and propagation of sound through the environment. While these models can provide accurate and source-specific noise estimates over large areas, they are also resource intensive and require detailed and accurate data on noise emissions (e.g., traffic volume, speed, fleet composition) and factors affecting sound propagation, such as: building geometry, materials, and density; road surface; as well as meteorology (Khan et al., 2018). As such, this may hinder their implementation in some LMICs where national governments or international corporations do not routinely collect the relevant input data, and at spatial and temporal resolutions useful for epidemiological applications (Clark et al., 2022; Raess et al., 2021; Sieber et al., 2017). Furthermore, limitations in input data can result in large errors in exposure estimates. The application of propagation-based noise models was uncommon (N = 10 studies) in the LMICs studies we reviewed, and 8 were rated as having a "*high*" or "*probably high*" ROB with regards to exposure assessment, largely because of limitations in, or lacking information on, input data (e.g., inclusion; spatial/temporal resolutions) and/or a lack of stated model validation (i.e., with local measurements). However, the increasing availability of publicly available global datasets (e.g., building footprints (Microsoft Open Source, 2022); Google traffic data), coupled with advancements in data/signal processing to generate new data (e.g., computer vision techniques applied to satellite and street-view imagery to detect road, roof, and façade characteristics (Weichenthal et al., 2019)) could help expand the use of propagation-based noise models in LMICs settings, and do so in a way that models are locally and contextually relevant.

Fixed-site measurements can be suitable for exposure assessment in epidemiological studies if accurate measurements are collected which are also representative of the exposure time frame of interest and capture variability of exposures across space and study participants (Staab et al., 2022). However, many of the reviewed studies evaluating chronic health outcomes and conditions collected a limited number of short-term measurements (i.e., 10 min–24 h), without repeat at the same locations on different days. This contributed to an assignment of "*high*" ROB in relation to exposure as measured exposures may not be representative of longer-time scales. Furthermore, some of the measurement-based studies had a low number of sites (<10) relative to the study area size, it was sometimes unclear if sites were appropriately sampled, and how exposures were assigned to study participants living nearby. In contrast, studies using personal exposure measurements collected with wearable devises were rated as "*low*" ROB as they, by design, capture exposure variations across space, but also individual time-activity patterns that influence daily exposures (Steinle et al., 2013).

Measurement-based approaches are often not logistically feasible for application in large-scale epidemiological studies (e.g., city/country-scale). Though, they can be used to validate propagation-based models, or to build and validate statistical-based models, such as land use regression (LUR) (Khan et al., 2018), which can predict exposures across large areas at unmeasured locations and at refined spatial scales. We found that only three studies in our review used LUR approaches, and due to limitations in the temporal/spatial resolution of input measurements (Dzhambov et al., 2018a; Dzhambov et al., 2019) and model validation (Sieber et al., 2018), all were rated as "*high*" and "*probably high*" ROB. However, many other noise LUR models developed for cities in Europe, North America, and Asia have achieved high predictive accuracies (e.g. (Liu et al., 2020; Walker et al., 2016; Aguilera et al., 2015; Harouvi et al., 2018; Ragettli et al., 2016; Staab et al., 2022; Wang et al., 2016) and LUR models have also recently been successfully developed for other LMICs cities, such as in Dalian (China) (Xie et al., 2011), Sao Paulo (Brazil) (Raess et al., 2021), and Accra ((Ghana) (Clark et al., 2022). LUR models based on robust measurements may be an attractive method for scaling up noise exposure assessment in epidemiological studies in LMICs settings as they can capture noise from a diversity of sources, leverage increasingly available global GIS predictor variable datasets (Microsoft Open Source, 2022; Brown et al., 2022; Barrington-Leigh and Millard-Ball, 2017), and can be implemented in cost-effective ways (Clark et al., 2020b).

Among the reviewed studies, we found mean levels of noise exposure ranging from 48.0 dB to 120.1 dB dB (L_{eq}). Over half of the studies (N = 31, 52.5%) reported a mean noise level ranging from 60 to 80 dB in the study areas. We also compared the exposure range from the 2018 WHO reviews and the present review (See Supplementary 12). Many studies in our review recorded elevated mean noise levels (range 55–80 dB L_{den}, N = 17), exceeding road-traffic noise health-based guidelines set by the WHO at 53 dB (L_{den}). Some studies around airports recorded aircraft noise ranging from 44 to 81 dB (L_{den}), exceeding the WHO guideline level for aircraft noise at 45 dB (L_{den}). One study for wind turbine noise ranged from 44.8 to 50.4 dB (L_{Aeq}) while WHO guideline level for wind turbine noise is set at 45 dB (L_{den}). It is possible that environmental noise pollution is likely more severe in some LMICs cities, where vehicle movement and fleet composition, exposure pattern, road geometry and conditions, noise standards, and mixtures of other community sources, can be contrastingly different from those in HICs; however, the exposure data from the reviewed studies is too limited and heterogeneous to make firm conclusions against the WHO guideline values.

4.4. Strength, limitations and future research directions

Methodologically, the value of our review lies in the wide-ranging systematic search strategy, the updated timeframe (2009–2021), the range of health outcomes considered, as well as the quality assessment of included studies. This review provides a comprehensive picture of the breadth and quality of noise effects on health studies in LMICs.

This review is subject to several limitations. First, it was a challenge conducting a unified ROB assessment for a pool of studies with heterogeneous study designs, exposure assessments, and health outcomes, and some of our ROB assessment ratings may be sensitive to the ROB assessment tool used. We also had to rely on the information given within each paper, and if critical details were missing, this would affect the ROB assessment as we did not discuss directly with each author due to the volume of reviewed studies. Also, there is a possibility of publication bias, i.e., there are chances that papers have been left out, if they have not been published in journals or conference proceedings due to reasons such as null findings. Also, we only included studies written in English, some of the literature from LMICs written in other languages may have been missed, which could have biased our results. Quantitative meta-analyses were not possible for this review given the unsuitability and limitations of the available data from these reviewed studies in LMICs.

Noise pollution, as evidenced in our review, is likely impacting many cities in LMICs. However, its public health impacts are often overlooked by the environmental health research community. We advocate that more high-quality epidemiological studies using robust and representative exposure assessment methods and population-based cohorts and/or electronic health records should be conducted, as well as well-designed interventional studies (Brown and Van Kamp, 2017). Evidence from these studies would assist local policymaking and actions in LMICs to reduce environmental noise exposures and reap substantial public health benefits.

5. Conclusion

To our knowledge, this is the first review to summarise current evidence on the relationships between environmental noise exposures and health outcomes in LMICs. Despite the majority of the overall ratings for ROB assessments were "*high*" or "*probably high*", we were able to gather some evidence on annoyance and physical health outcomes such as cardiovascular health. Meta-analyses were not possible as studies on a given health outcome were either too heterogeneous or too few. This review has provided a critical analysis on important knowledge gaps for the noise and health research community in LMICs to address in the near future.

Author statement

ALH conceived the study idea. YC searched, reviewed and analysed the literature, and wrote the first draft of manuscript. SC and YSC provided inputs on literature search and interpretation of the literature. ALH and YSC supervised the study, and ALH, SC and YSC revised the original draft with intellectual inputs. YSC is the guarantor of the paper. All authors approved the submission.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary data

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References

Agarwal, S., Swami, B., 2010. Noise annoyance under interrupted traffic flow condition for Jaipur city. Int. J. Appl. Sci. Eng. 7, 159–168.
Agarwal, S., Swami, B.L., 2011. Road traffic noise, annoyance and community health survey-A case study for an Indian city. Noise Health 13, 272.
Aguilera, I, Foraster, M, Basagaña, X, Corradi, E, Deltell, A, Morelli, X, Phuleria, H.C, Ragettli, M.S, Rivera, M, Thomasson, A, Slama, R, 2015. Application of land use regression modelling to assess the spatial distribution of road traffic noise in three European cities. Journal of exposure science & environmental epidemiology 25 (1), 97–105.
Ali, A., Hussain, R.M., Dom, N.C., Rashid, R.I.M., 2018. A profile of noise sensitivity on the health-related quality of life among young motorcyclists. Noise Health 20, 53.
Ana, G.R.E.E., Shendell, D.G., Brown, G.E., Sridhar, M.K.C., 2009. Assessment of noise and associated health impacts at selected secondary schools in ibadan, Nigeria. Journal of Environmental and Public Health 2009, 739502.
Argalášová-Sobotová, L.U., Lekaviciute, J., Jeram, S., Ševcíková, L.U., Jurkovicová, J., 2013. Environmental noise and cardiovascular disease in adults: research in central, eastern and south-eastern Europe and newly independent states. Noise Health 15, 22.
Babisch, W., 2002. The noise/stress concept, risk assessment and research needs. Noise Health 4, 1.
Baloye, D.O., Palamuleni, L.G., 2015. A comparative land use-based analysis of noise pollution levels in selected urban centers of Nigeria. Int. J. Environ. Res. Publ. Health 12, 12225–12246.
Banerjee, D., 2012. Research on road traffic noise and human health in India: review of literature from 1991 to current. Noise Health 14, 113.
Banerjee, D., 2013. Road traffic noise exposure and annoyance: a cross-sectional study among adult Indian population. Noise Health 15, 342.
Banerjee, D., Chakraborty, S., Bhattacharyya, S., Gangopadhyay, A., 2009. Attitudinal response towards road traffic noise in the industrial town of Asansol, India. Environ. Monit. Assess. 151, 37–44.
Banerjee, D., Das, P.P., Foujdar, A., 2014a. Association between road traffic noise and prevalence of coronary heart disease. Environ. Monit. Assess. 186, 2885–2893.
Banerjee, D., Das, P.P., Fouzdar, A., 2014b. Urban residential road traffic noise and hypertension: a cross-sectional study of adult population. J. Urban Health 91, 1144–1157.
Barrington-Leigh, C., Millard-Ball, A., 2017. The world's user-generated road map is more than 80% complete. PLoS One 12, e0180698.
Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S., 2014. Auditory and non-auditory effects of noise on health. The lancet 383, 1325–1332.
Basner, M., Mcguire, S., 2018. WHO environmental noise guidelines for the European region: a systematic review on environmental noise and effects on sleep. Int. J. Environ. Res. Publ. Health 15, 519.
Belojevic, G., Evans, G.W., Paunovic, K., Jakovljevic, B., 2012. Traffic noise and executive functioning in urban primary school children: the moderating role of gender. J. Environ. Psychol. 32, 337–341.
Belojevic, G., Paunovic, K., Jakovljevic, B., Stojanov, V., Ilic, J., Slepcevic, V., Saric-Tanaskovic, M., 2011. Cardiovascular effects of environmental noise: research in Serbia. Noise Health 13, 217.
Brown, A.L., Van Kamp, I., 2017. WHO environmental noise guidelines for the European region: a systematic review of transport noise interventions and their impacts on health. Int. J. Environ. Res. Publ. Health 14, 873.
Brown, C.F., Brumby, S.P., Guzder-Williams, B., Birch, T., Hyde, S.B., Mazzariello, J., Czerwinski, W., Pasquarella, V.J., Haertel, R., Ilyushchenko, S., 2022. Dynamic World, Near real-time global 10 m land use land cover mapping. Sci. Data 9, 1–17.
Cai, M., Zou, J., Xie, J., Ma, X., 2015. Road traffic noise mapping in Guangzhou using GIS and GPS. Appl. Acoust. 87, 94–102.
Clark, C., Crumpler, C., Notley, A.H., 2020a. Evidence for environmental noise effects on health for the United Kingdom policy context: a systematic review of the effects of environmental noise on mental health, wellbeing, quality of life, cancer, dementia, birth, reproductive outcomes, and cognition. Int. J. Environ. Res. Publ. Health 17.
Clark, C., Paunovic, K., 2018a. WHO environmental noise guidelines for the european region: a systematic review on environmental noise and cognition. Int. J. Environ. Res. Publ. Health 15, 285.
Clark, C., Paunovic, K., 2018b. WHO Environmental noise guidelines for the European Region: a systematic review on environmental noise and quality of life, wellbeing and mental health. Int. J. Environ. Res. Publ. Health 15, 2400.
Clark, S.N., Alli, A.S., Brauer, M., Ezzati, M., Baumgartner, J., Toledano, M.B., Hughes, A. F., Nimo, J., Moses, J.B., Terkpertey, S., 2020b. Protocol: high-resolution spatiotemporal measurement of air and environmental noise pollution in sub-saharan African cities: pathways to equitable health cities study protocol for Accra, Ghana. BMJ Open 10.
Clark, S.N., Alli, A.S., Ezzati, M., Brauer, M., Toledano, M.B., Nimo, J., Moses, J.B., Baah, S., Hughes, A., Cavanaugh, A., 2022. Spatial modelling and inequalities of environmental noise in Accra, Ghana. Environ. Res. 214, 113932.
Daruis, D.D.I., Awang, N.W., Deros, B.M., Ismail, A.R., 2014. The effects of night-time road traffic noise on discomfort-A case study in Dungun, Terengganu, Malaysia. Iran. J. Public Health 43, 58–66.
Debnath, A., Singh, P.K., 2018. Environmental traffic noise modelling of Dhanbad township area – a mathematical based approach. Appl. Acoust. 129, 161–172.
Dias, F.a.M., Caiaffa, W.T., Costa, D.a.D.S., Xavier, C.C., Proietti, F.A., Friche, A.a.D.L., 2021. Noise annoyance, sociodemographic and health patterns, and neighborhood perceptions in a Brazilian metropolis: BH Health Study. Revista brasileira de epidemiologia = Brazilian journal of epidemiology 24, e210038.
Dzhambov, A., Dimitrova, D., 2014. Neighborhood noise pollution as a determinant of displaced aggression: a pilot study. Noise Health 16, 95.
Dzhambov, A., Tilov, B., Markevych, I., Dimitrova, D., 2017. Residential road traffic noise and general mental health in youth: the role of noise annoyance, neighborhood restorative quality, physical activity, and social cohesion as potential mediators. Environ. Int. 109, 1–9.
Dzhambov, A.M., Dimitrova, D.D., 2015. Road traffic noise exposure association with self-reported body mass index. Noise Control Eng. J. 63, 572–581.
Dzhambov, A.M., Dimitrova, D.D., 2016. Exposures to road traffic, noise, and air pollution as risk factors for type 2 diabetes: a feasibility study in Bulgaria. Noise Health 18, 133.
Dzhambov, A.M., Dimitrova, D.D., Dzhambov, A., 2016. Association between noise pollution and prevalent ischemic heart disease. Folia Med. (Plovdiv) 58, 273–281.
Dzhambov, A.M., Markevych, I., Tilov, B., Arabadzhiev, Z., Stoyanov, D., Gatseva, P., Dimitrova, D.D., 2018a. Pathways linking residential noise and air pollution to mental ill-health in young adults. Environ. Res. 166, 458–465.
Dzhambov, A.M., Markevych, I., Tilov, B.G., Dimitrova, D.D., 2018b. Residential greenspace might modify the effect of road traffic noise exposure on general mental health in students. Urban For. Urban Green. 34, 233–239.
Dzhambov, A.M., Tilov, B., Makakova-Tilova, D., Dimitrova, D.D., 2019. Pathways and contingencies linking road traffic noise to annoyance, noise sensitivity, and mental Ill-Health. Noise Health 21, 248–257.
Farooqi, Z.U.R., Ahmad, I., Zeeshan, N., Ilic, P., Imran, M., Saeed, M.F., 2021. Urban noise assessment and its nonauditory health effects on the residents of Chiniot and Jhang, Punjab, Pakistan. Environ. Sci. Pollut. Res. Int. 28 (39), 54909–54921.
Firdaus, G., Ahmad, A., 2010. Noise pollution and human health: a case study of Municipal Corporation of Delhi. Indoor Built Environ. 19, 648–656.
Gilani, T.A., Mir, M.S., 2021. Association of road traffic noise exposure and prevalence of coronary artery disease: a cross-sectional study in North India. Environ. Sci. Pollut. Res. Int.
Gjestland, T., Nguyen, T.L., Yano, T., 2015. Community response to noise in Vietnam: exposure-response relationships based on the community tolerance level. J. Acoust. Soc. Am. 137, 2596–2601.
Goswami, S., 2009. Road traffic noise: a case study of Balasore town, Orissa, India. Int. J. Environ. Res. 3, 309–318.
Goswami, S., Nayak, S.K., Pradhan, A.C., Dey, S.K., 2011. A study on traffic noise of two campuses of University, Balasore, India. J. Environ. Biol. 32, 105–109.

Guoqing, D., Xiaoyi, L., Xiang, S., Zhengguang, L., Qili, L., 2012. Investigation of the relationship between aircraft noise and community annoyance in China. Noise Health 14, 52.
Guski, R., Schreckenberg, D., Schuemer, R., 2017. WHO environmental noise guidelines for the European region: a systematic review on environmental noise and annoyance. Int. J. Environ. Res. Publ. Health 14.
Hamid, A., Akhtar, S., Atique, S.A., Huma, Z., Mohay Uddin, S.G., Asghar, S., 2019. Ambient air quality & noise level monitoring of different areas of lahore (Pakistan) and its health impacts. Pol. J. Environ. Stud. 28.
Han, Z.-X., Lei, Z.-H., Zhang, C.-L., Xiong, W., Gan, Z.-L., Hu, P., Zhang, Q.-B., 2015. Noise monitoring and adverse health effects in residents in different functional areas of Luzhou, China. Asia Pac. J. Publ. Health 27, 93S–99S.
Harouvi, O, Ben-Elia, E, Factor, R, de Hoogh, K, Kloog, I, 2018. Noise estimation model development using high-resolution transportation and land use regression. Expo Sci Environ Epidemiol 28, 67–559.
Hegewald, J., Schubert, M., Freiberg, A., Romero Starke, K., Augustin, F., Riedel-Heller, S.G., Zeeb, H., Seidler, A., 2020a. Traffic noise and mental health: a systematic review and meta-analysis. Int. J. Environ. Res. Publ. Health 17.
Hegewald, J., Schubert, M., Freiberg, A., Romero Starke, K., Augustin, F., Riedel-Heller, S.G., Zeeb, H., Seidler, A., 2020b. Traffic noise and mental health: a systematic review and meta-analysis. Int. J. Environ. Res. Publ. Health 17, 6175.
Huang, J., Deng, F., Wu, S., Lu, H., Hao, Y., Guo, X., 2013. The impacts of short-term exposure to noise and traffic-related air pollution on heart rate variability in young healthy adults. J. Expo. Sci. Environ. Epidemiol. 23, 559–564.
International Civil Aviation Organization, 2019. The Next Chapter.
Johnson, P.I., Koustas, E., Vesterinen, H.M., Sutton, P., Atchley, D.S., Kim, A.N., Campbell, M., Donald, J.M., Sen, S., Bero, L., 2016. Application of the Navigation Guide systematic review methodology to the evidence for developmental and reproductive toxicity of triclosan. Environ. Int. 92, 716–728.
Khan, J., Ketzel, M., Kakosimos, K., Sørensen, M., Jensen, S.S., 2018. Road traffic air and noise pollution exposure assessment–A review of tools and techniques. Sci. Total Environ. 634, 661–676.
Lepore, S.J., Shejwal, B., Kim, B.H., Evans, G.W., 2010. Associations between chronic community noise exposure and blood pressure at rest and during acute noise and non-noise stressors among urban school children in India. Int. J. Environ. Res. Publ. Health 7, 3457–3466.
Liu, Y., Goudreau, S., Oiamo, T., Rainham, D., Hatzopoulou, M., Chen, H., Davies, H., Tremblay, M., Johnson, J., Bockstael, A., 2020. Comparison of land use regression and random forests models on estimating noise levels in five Canadian cities. Environ. Pollut. 256, 113367.
Liu, Y., Xia, B., Cui, C., Skitmore, M., 2017. Community response to construction noise in three central cities of Zhejiang province, China. Environ. Pollut. 230, 1009–1017.
Ma, J., Li, C., Kwan, M.-P., Chai, Y., 2018. A multilevel analysis of perceived noise pollution, geographic contexts and mental health in Beijing. Int. J. Environ. Res. Publ. Health 15, 1479.
Ma, J., Li, C., Kwan, M.-P., Kou, L., Chai, Y., 2020. Assessing personal noise exposure and its relationship with mental health in Beijing based on individuals' space-time behavior. Environ. Int. 139, 105737.
Masoudzadeh, A., Hadinezhad, P., Gooran, M., 2017. Comparison of mental health status of people exposed to noise pollution with people in non-polluted areas of sari. Health 9, 839.
Microsoft Open Source, 2022. Microsoft/GlobalML Building Footprints. Github.Com: Microsoft.
Morinaga, M., Nguyen, T.L., Shimoyama, K., Yokoshima, S., Yano, T., 2020. Effects of step change in aircraft noise exposure on activity disturbances: socio-acoustic surveys around Hanoi Noi Bai International Airport. Acoust Sci. Technol. 41, 590–597.
Moroe, N., Mabaso, P., 2022. Quantifying traffic noise pollution levels: a cross-sectional survey in South Africa. Sci. Rep. 12, 1–11.
Münzel, T., Sørensen, M., Daiber, A., 2021. Transportation noise pollution and cardiovascular disease. Nat. Rev. Cardiol. 18, 619–636.
Nandanwar, D., Parbat, D.K., Deshmukh, S., 2009. Study on residents perception and attitudes towards urban traffic noise in Nagpur city. In: 2009 Second International Conference on Emerging Trends in Engineering & Technology. IEEE, pp. 585–588.
Nazneen, S., Raza, A., Khan, S., 2020. Assessment of noise pollution and associated subjective health complaints and psychological symptoms: analysis through structure equation model. Environ. Sci. Pollut. Res. Int. 27, 21570–21580.
Nguyen, T.L., Nguyen, T.L., Morinaga, M., Yokoshima, S., Yano, T., Sato, T., Yamada, I., 2018. Community response to a step change in the aircraft noise exposure around Hanoi Noi Bai International Airport. J. Acoust. Soc. Am. 143, 2901–2912.
Nguyen, T.L., Trieu, B.L., Hiraguri, Y., Morinaga, M., Morihara, T., Yano, T., 2020. Effects of changes in acoustic and non-acoustic factors on public health and reactions: follow-up surveys in the vicinity of the Hanoi Noi Bai international airport. Int. J. Environ. Res. Publ. Health 17, 2597.
Nguyen, T.L., Yano, T., Nguyen, H.Q., Nishimura, T., Fukushima, H., Sato, T., Morihara, T., Hashimoto, Y., 2011. Community response to aircraft noise in Ho Chi Minh city and Hanoi. Appl. Acoust. 72, 814–822.
Nilsson, M., 2018. Biological Mechanisms Related to Cardiovascular and Metabolic Effects by Environmental Noise.
Okokon, E.O., Taimisto, P., Turunen, A.W., Amoda, O.A., Fasasi, A.E., Adeyemi, L.G., Juutilainen, J., Lanki, T., 2018. Particulate air pollution and noise: assessing commuter exposure in Africa's most populous city. J. Transport Health 9, 150–160.
Onchang, R., Hawker, D.W., 2018. Community noise exposure and annoyance, activity interference, and academic achievement among university students. Noise Health 20, 69.
Paiva, K.M., Cardoso, M.R.A., Zannin, P.H.T., 2019. Exposure to road traffic noise: annoyance, perception and associated factors among Brazil's adult population. Sci. Total Environ. 650, 978–986.
Paunovic, K., Belojevic, G., Jakovljevic, B., 2013. Blood pressure of urban school children in relation to road-traffic noise, traffic density and presence of public transport. Noise Health 15, 253.
Paunović, K., Belojević, G., Jakovljević, B., 2014. Noise annoyance is related to the presence of urban public transport. Sci. Total Environ. 481, 479–487.
Phan, H.Y.T., Yano, T., Phan, H.a.T., Nishimura, T., Sato, T., Hashimoto, Y., 2010. Community responses to road traffic noise in Hanoi and Ho Chi Minh city. Appl. Acoust. 71, 107–114.
Raess, M., Brentani, A., De Campos, B.L.D.A., Flückiger, B., De Hoogh, K., Fink, G., Röösli, M., 2021. Land use regression modelling of community noise in São Paulo, Brazil. Environ. Res. 199, 111231.
Ragettli, M.S, Goudreau, S, Plante, C, Fournier, M, Hatzopoulou, M, Perron, S, Smargiassi, A, 2016.. Statistical modeling of the spatial variability of environmental noise levels in Montreal, Canada, using noise measurements and land use characteristics. Journal of Exposure Science & Environmental Epidemiology 26 (6), 597–605.
Ravindra, Singh, T., Tripathy, J.P., Mor, S., Munjal, S., Patro, B., Panda, N., 2016. Assessment of noise pollution in and around a sensitive zone in North India and its non-auditory impacts. Sci. Total Environ. 566–567, 981–987.
Ristovska, G., Gjorgjev, D., Polozhani, A., Kočubovski, M., Kendrovski, V., 2009. Environmental noise and annoyance in adult population of Skopje: a cross-sectional study. Arh. Hig. Rad. Toksikol. 60, 349–355.
Roca-Barcelo, A., Nardocci, A., De Aguiar, B.S., Ribeiro, A.G., Failla, M.A., Hansell, A.L., Cardoso, M.R., Piel, F.B., 2021. Risk of cardiovascular mortality, stroke and coronary heart mortality associated with aircraft noise around Congonhas airport, Sao Paulo, Brazil: a small-area study. Environ. Health : Global Access Sci. Source 20, 59.
Seabi, J., 2013. An epidemiological prospective study of children's health and annoyance reactions to aircraft noise exposure in South Africa. Int. J. Environ. Res. Publ. Health 10, 2760–2777.
Seabi, J., Cockcroft, K., Goldschagg, P., Greyling, M., 2012. The impact of aircraft noise exposure on South African children's reading comprehension: the moderating effect of home language. Noise Health 14, 244.
Seabi, J., Cockcroft, K., Goldschagg, P., Greyling, M., 2015. A prospective follow-up study of the effects of chronic aircraft noise exposure on learners' reading comprehension in South Africa. J. Expo. Sci. Environ. Epidemiol. 25, 84–88.
Siddiqui, I.A., Nizami, S., Chandio, R.R., Nizami, S., Sikander, N., Ashraf, S., 2015. Consequences of traffic noise in residents of Karachi, Pakistan. Pakistan J. Med. Sci. 31, 448.
Sieber, C., Ragettli, M.S., Brink, M., Olaniyan, T., Baatjies, R., Saucy, A., Vienneau, D., Probst-Hensch, N., Dalvie, M.A., Roosli, M., 2018. Comparison of sensitivity and annoyance to road traffic and community noise between a South African and a Swiss population sample. Environ. Pollut. 241, 1056–1062.
Sieber, C., Ragettli, M.S., Brink, M., Toyib, O., Baatjies, R., Saucy, A., Probst-Hensch, N., Dalvie, M.A., Röösli, M., 2017. Land use regression modeling of outdoor noise exposure in informal settlements in Western Cape, South Africa. Int. J. Environ. Res. Publ. Health 14, 1262.
Smith, M.G., Cordoza, M., Basner, M., 2022. Environmental noise and effects on sleep: an update to the WHO systematic review and meta-analysis. Environ. Health Perspect. 130, 076001.
Song, K., Di, G., Xu, Y., Chen, X., 2016. Community survey on noise impacts induced by 2 MW wind turbines in China. J. Low Freq. Noise Vib. Act. Control 35, 279–290.
Staab, J, Schady, A, Weigand, M, Lakes, T, Taubenböck, H, et al., 2022. Predicting traffic noise using land-use regression—a scalable approach. Journal of exposure science & environmental epidemiology 32 (2), 232–243.
Staab, J., Schady, A., Weigand, M., Lakes, T., Taubenböck, H., 2022. Predicting traffic noise using land-use regression—a scalable approach. J. Expo. Sci. Environ. Epidemiol. 32, 232–243.
Steinle, S., Reis, S., Sabel, C.E., 2013. Quantifying human exposure to air pollution—moving from static monitoring to spatio-temporally resolved personal exposure assessment. Sci. Total Environ. 443, 184–193.
Stošić, L., Belojević, G., Milutinović, S., 2009. Effects of traffic noise on sleep in an urban population. Arh. Hig. Rada. Toksikol. 60, 335–342.
Tao, Y., Chai, Y., Kou, L., Kwan, M.-P., 2020. Understanding noise exposure, noise annoyance, and psychological stress: incorporating individual mobility and the temporality of the exposure-effect relationship. Appl. Geogr. 125, 102283.
Tao, Y., Kou, L., Chai, Y., Kwan, M.-P., 2021. Associations of co-exposures to air pollution and noise with psychological stress in space and time: a case study in Beijing, China. Environ. Res. 196, 110399.
Teixeira, L.R., Azevedo, T.M., Bortkiewicz, A., Da Silva, D.T.C., De Abreu, W., De Almeida, M.S., De Araujo, M.A., Gadzicka, E., Ivanov, I.D., Leppink, N., 2019. WHO/ILO work-related burden of disease and injury: protocol for systematic reviews of exposure to occupational noise and of the effect of exposure to occupational noise on cardiovascular disease. Environ. Int. 125, 567–578.
Teixeira, L.R., Pega, F., Dzhambov, A.M., Bortkiewicz, A., Da Silva, D.T.C., De Andrade, C.a.F., Gadzicka, E., Hadkhale, K., Iavicoli, S., Martínez-Silveira, M.S., Pawlaczyk-Łuszczyńska, M., Rondinone, B.M., Siedlecka, J., Valenti, A., Gagliardi, D., 2021. The effect of occupational exposure to noise on ischaemic heart disease, stroke and hypertension: a systematic review and meta-analysis from the WHO/ILO Joint Estimates of the Work-Related Burden of Disease and Injury. Environ. Int. 154, 106387.
Thompson, R., Smith, R.B., Bou Karim, Y., Shen, C., Drummond, K., Teng, C., Toledano, M.B., 2022a. Noise pollution and human cognition: an updated systematic review and meta-analysis of recent evidence. Environ. Int. 158, 106905.

Thompson, R., Smith, R.B., Karim, Y.B., Shen, C., Drummond, K., Teng, C., Toledano, M. B., 2022b. Noise pollution and human cognition: an updated systematic review and meta-analysis of recent evidence. Environ. Int. 158, 106905.

Trieu, B.L., Nguyen, T.L., Hiraguri, Y., Morinaga, M., Morihara, T., 2021. How does a community respond to changes in aircraft noise? A comparison of two surveys conducted 11 years apart in Ho Chi Minh City. Int. J. Environ. Res. Publ. Health 18, 4307.

Van Kamp, I., Simon, S., Notley, H., Baliatsas, C., Van Kempen, E., 2020. Evidence relating to environmental noise exposure and annoyance, sleep disturbance, cardio-vascular and metabolic health outcomes in the context of IGCB (N): a scoping review of new evidence. Int. J. Environ. Res. Publ. Health 17, 3016.

Van Kempen, E., Babisch, W., 2012. The quantitative relationship between road traffic noise and hypertension: a meta-analysis. J. Hypertens. 30, 1075–1086.

Van Kempen, E., Casas, M., Pershagen, G., Foraster, M., 2018. WHO environmental noise guidelines for the European region: a systematic review on environmental noise and cardiovascular and metabolic effects: a summary. Int. J. Environ. Res. Publ. Health 15.

Walker, E.D., Brammer, A., Cherniack, M.G., Laden, F., Cavallari, J.M., 2016. Cardiovascular and stress responses to short-term noise exposures—a panel study in healthy males. Environ. Res. 150, 391–397.

Wang, VS, Lo, EW, Liang, CH, Chao, KP, Bao, BY, Chang, TY, 2016. Temporal and spatial variations in road traffic noise for different frequency components in metropolitan Taichung, Taiwan. 2016; **219**: 174–81. Environ Pollut 219, 81–174.

Weichenthal, S., Hatzopoulou, M., Brauer, M., 2019. A picture tells a thousand… exposures: opportunities and challenges of deep learning image analyses in exposure science and environmental epidemiology. Environ. Int. 122, 3–10.

World Health Organization, 2011. Burden of disease from environmental noise. In: Burden of Disease from Environmental Noise.

World Health Organization, 2018. Noise Guidelines for the European Region. WHO Regional Office for Europe.

Wu, J., Zou, C., He, S., Sun, X., Wang, X., Yan, Q., 2019. Traffic noise exposure of high-rise residential buildings in urban area. Environ. Sci. Pollut. Control Ser. 26, 8502–8515.

Xie, D., Liu, Y., Chen, J., 2011. Mapping urban environmental noise: a land use regression method. Environ. Sci. Technol. 45, 7358–7364.

Zamorano-Gonzalez, B., Pena-Cardenas, F., Velazquez-Narvaez, Y., Parra-Sierra, V., Vargas-Martinez, J.I., Monreal-Aranda, O., Ruiz-Ramos, L., 2021. Traffic noise annoyance in the population of North Mexico: case study on the daytime period in the city of matamoros. Front. Psychol. 12, 657428.

Zare Sakhvidi, M., Zare Sakhvidi, F., Mehrparvar, A., Foraster, M., Dadvand, P., 2018. In: Association between Noise Exposure and Diabetes: A Systematic Review and Meta-Analysis, vol. 166, pp. 647–657.