RevistaCEFAC
Current Evidence on Feeding, Audiology and Communication

eISSN 1982-0216

DOI: 10.1590/1982-0216/20252732924 | Rev. CEFAC. 2025;27(3):e2924

Review articles

Measurements of urban noise and its impact on human health: A scoping review

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A study conducted at the Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil.

Financial support: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) – Finance Code 001

Conflict of interests: Stela Maris Aguiar Lemos declares she is an editorial board member of Revista CEFAC but was not involved in the peer review or editorial decision-making process for this article

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Received on March 23, 2024
Received in a revised form on May 29, 2024
Accepted on April 2, 2025

Chief Editor: Hilton Justino da Silva
Associate Editor: Kelly da Silva

ABSTRACT

Purpose: to review scientific literature on urban noise measurement methods and its effects on human health.

Methods: this scoping review of urban noise measurement methods and its effects on human health surveyed the following scientific databases: VHL, LILACS, PubMed, MEDLINE, Cochrane Library, and Scopus. It included articles that investigated the effects of urban noise on human health and described noise measurement methods and values in decibels (dB) and excluded those reporting the effects of urban noise on animal health.

Literature Review: the final sample comprised 33 articles. Noise measurement, using the logarithmic scale, has become more widely used in recent years. The main health effects of noise were stress or irritability, sleep disturbances, cardiovascular diseases, interference with activities of daily living and/or quality of life, increased heart or respiratory rate, hearing impairment and tinnitus, and breast cancer.

Conclusion: the effects of urban noise on human health are most evident in extra-auditory symptoms. It is necessary to develop and validate reliable instruments to measure people's perception of urban noise.

Keywords: Noise; Noise, Transportation; Noise Effects; Public Health; Quality of Life

INTRODUCTION

Urban noise is undoubtedly a public health problem. The advent of technology, the expansion of transportation, and the increased concentration of people in urban centers have been cited in the literature as the main sources of urban noise worldwide[1]. The World Health Organization (WHO) classifies urban noise as noise pollution. Despite its obvious impacts on human health, it is still overlooked by a large portion of the population[2].

The presence of urban noise interferes with the daily lives of residents and workers in large cities, directly impacting their well-being. Regardless of the noise source – whether urban noise or noise from sound devices, occupational noise, or recreational activities – it is recognized for its harmful effects[3]. The literature presents evidence linking the effect of noise to sleep disorders, discomfort, risk of cardiovascular disease, interference with activities of daily living, anger, displeasure, exhaustion, and stress[4-7].

The degree of noise's harmfulness to cause such damage depends on factors such as exposure time and emission intensity. The rules established by the Brazilian Association of Technical Standards (ABNT) through NBR 10.152 and 10.151 set limits for indoor and outdoor noise levels and for noise that causes interference inside homes[8]. According to NBR 10.151, the maximum permitted values to avoid harm to health are 60 dB during the day and 55 dB at night[8]. Sound intensity above these levels affects the population's quality of life. Other countries also have regulations establishing maximum acceptable noise levels in urban areas. Following the WHO's warning about the effects of noise, Directive 2002/49/EC stands out in Europe, setting the maximum road traffic noise level at 55 dB during the day and 50 dB at night[9]. Moreover, Germany established that traffic noise should not exceed 53 dB during the day and 45 dB at night[9]. In Asia, Japan stands out for its guidelines that establish a limit of 60 dB for residential areas during the day and 50 dB at night[10]. Despite these guidelines and laws, all these countries are subject to noise levels higher than those established, as described elsewhere[2,11-14]. This situation is worrying and demands discussion among all sectors of society.

In addition to auditory effects, there is evidence of other health problems caused by continuous noise exposure and impacts on quality of life[9]. Although the literature described auditory and non-auditory effects of noise, it was appropriate to conduct a scoping review to systematically map the publications produced on this topic and identify any gaps in knowledge. Thus, to further contribute to the compilation of the main methods for investigating urban noise and reduce potential confusion regarding which logarithmic units the specialized literature uses, the research question was, "What methods are used to measure urban noise and what are its main impacts on human health?"

METHODS

Research protocol and eligibility criteria

This scoping review aimed to investigate the methods of measuring urban noise, as well as its effects on human health. The protocol for this review was registered in the public OSF database under the DOI: 10.17605/OSF.IO/Z98SK.

First, the research question was formulated using the PCC strategy, in which P (Population) referred to human studies; C (Concept), to measurement methods and levels of urban noise; and C (Context), to the effects of urban noise on human health. The research question was, "What methods are used to measure urban noise and what are its main impacts on human health?"

This review included scientific articles and papers from gray literature and all studies investigating urban noise levels and its relationship with human health for any age group, describing the harm caused by noise and its values in decibels (dB) and dB(A). The inclusion period for the articles was from 2012 to 2022, aiming to cover the most current evidence on the topic. The database search period was from February to September 2023. This review is presented according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses – Extension for Scoping Reviews (PRISMA-ScR)[15].

Table 1. Development of the research question and establishment of inclusion and exclusion criteria

Category	Inclusion	Exclusion
Population	Studies that focused on children, adults, or the elderly.	Studies related to animal and occupational health.
Concept	Urban noise; environmental noise; traffic noise (air, water, or land). Presentation of noise measurements and standards (devices used, measurement protocols)	Noise in school environments; military infantry noise; industrial noise. Studies that did not report this information
Context	Effects on physical, emotional, mental, and cognitive health. Disturbance, discomfort, sleep disturbance.	Studies that did not link noise to health. Unreported or unrelated health conditions.

Databases and article searches

The articles were searched in the VHL, Cochrane Library, Medline, and Scopus portals. The LILACS database was accessed via the VHL portal, and the Medline database was accessed via the PubMed portal. The searches were conducted separately by two reviewers, both following the same criteria for evaluation, inclusion, and exclusion of articles. A consensus meeting was held among the reviewers, and all disagreements were resolved. Article selection involved the identification of controlled terms (DeCS/MeSH descriptors) and free terms (keywords).

The search used descriptors in Portuguese, French, Spanish, and English: "Ruído", ("Bruit"), ("Ruido), ("Noise"); "Ruído dos Transportes", ("Bruit des transports"), ("Ruido del transporte"), ("Noise, Transportation"); "Efeitos do ruído", ("Effets du bruit"), ("Efectos del ruido"), ("Noise effects"); "Saúde Pública", ("Santé Publique"), ("Salud Pública"), ("Public Health"); "Qualidade de vida", ("Qualité de vie"), ("Quality of life"). Free terms, such as synonyms, related terms, spelling variations, acronyms, and keywords were also used, namely: Ruído Urbano, Urban Noise, Noise Pollution, Noises, Transportation Noise, Transportation Noises, HRQOL, Health Related Quality of Life, Health-Related Quality of Life, Life Quality.

These descriptors and terms were organized into search equations using AND and OR operators. The search equations were adapted to each database (Table 1), as each has unique search mechanisms. Gray literature used in this review came from VHL, as it allows for the filtering of such publications.

Table 2. Database search strategies

Database	Strategy
LILACS via VHL*	(ruído OR noise OR ruido OR bruit OR barulho OR barulhos OR "Contaminação Sonora" OR "Poluição Acústica" OR "Poluição Sonora" OR ruídos OR "Ruído dos Transportes" OR "Noise, Transportation" OR "Ruido del Transporte" OR "Bruit des transports" OR "Poluição Sonora Associada aos Transportes" OR "Poluição Sonora Causada por Transportes" OR "Poluição Sonora Gerada por Transportes" OR "Poluição Sonora Provocada por Transportes" OR "Poluição Sonora Veicular" OR "Poluição Sonora de Veículo Automotor" OR "Poluição Sonora do Transporte" OR "Ruído Associado aos Transportes" OR "Ruído Causado por Transportes" OR "Ruído Gerado por Transportes" OR "Ruído Provocado por Transportes" OR "Ruído Veicular" OR "Ruído de Transporte" OR "Ruído do Transporte" OR "Ruído dos Meios de Transporte" OR "Ruído Urbano" OR "Urban Noise" OR "Noise Pollution" OR noises OR "Transportation Noise" OR "Transportation Noises") AND ("Efeitos do Ruído" OR "Noise Effects" OR "Efectos del Ruido" OR "Effets du Bruit" OR "Saúde Pública" OR "Public Health" OR "Salud Pública" OR "Santé publique" OR "Qualidade de Vida" OR "Quality of Life" OR "Calidad de Vida" OR "Qualité de vie" OR "HRQOL" OR "QVRS" OR "Qualidade de Vida Relacionada à Saúde" OR "Health Related Quality Of Life" OR "Health-Related Quality Of Life" OR "Life Quality")
MEDLINE via PubMed	(Noise OR "Noise, Transportation" OR "Urban Noise" OR "Noise Pollution" OR Noises OR "Transportation Noise" OR "Transportation Noises") AND ("Noise Effects" OR "Public Health" OR "Quality of Life" OR HRQOL OR "Health Related Quality of Life" OR "Health-Related Quality of Life" OR "Life Quality")
Cochrane Library	(Noise OR "Noise, Transportation" OR "Urban Noise" OR "Noise Pollution" OR Noises OR "Transportation Noise" OR "Transportation Noises") AND ("Noise Effects" OR "Public Health" OR "Quality of Life" OR HRQOL OR "Health Related Quality of Life" OR "Health-Related Quality of Life" OR "Life Quality")
Scopus	(Noise OR "Noise, Transportation" OR "Urban Noise" OR "Noise Pollution" OR Noises OR "Transportation Noise" OR "Transportation Noises") AND ("Noise Effects" OR "Public Health" OR "Quality of Life" OR HRQOL OR "Health Related Quality of Life" OR "Health-Related Quality of Life" OR "Life Quality")

*MEDLINE results were excluded from VHL as they were analyzed via PubMed

Selection from databases and articles

The search results were imported into an Excel spreadsheet, and the titles and abstracts were independently screened by two reviewers. There were no disagreements at this stage, so the full texts were also independently screened and read by the same two reviewers. At this stage, disagreements were resolved in meetings, eliminating the need to invite a third reviewer to reach consensus. Finally, the following data were collected from the remaining articles:

- Year of publication.
- City/country where the research was conducted.
- Study sample.
- Study design.
- Instruments and methods of noise measurement.
- Urban noise levels found.
- Relationship between measurements and human health.

The studies included in the review were organized into two charts: one with reviewed scientific articles and the other containing dissertations and theses, highlighting the relevant data of interest to the research.

LITERATURE REVIEW

Selection from databases and articles

The databases were searched from February to September 2023, identifying 568 articles in the VHL Portal, 581 in the PubMed database, 50 in the Cochrane Library, and 1,656 in the Scopus database, totaling 2,855 articles. After screening, 2,482 articles were excluded in the stage prior to full reading, the most prevalent justification for this being the lack of a relationship between titles and abstracts and the research topic. A total of 373 articles remained for full-text reading. Some articles could only be accessed in full via the Capes Portal and Acesso CAFe. After reading them in full, 340 articles were excluded, the most prevalent justification being the lack of noise measurement methods, followed by a focus on occupational hearing health and unreported or related health conditions. Other justifications for excluding articles are presented in the PRISMA-ScR flowchart (Figure 1).

Characteristics of articles across databases

After the steps of identifying, screening, and applying eligibility criteria to articles across platforms, 33 articles remained eligible for full reading. Of these, 11 articles came from VHL.[7-13], two from PubMed[21,22],

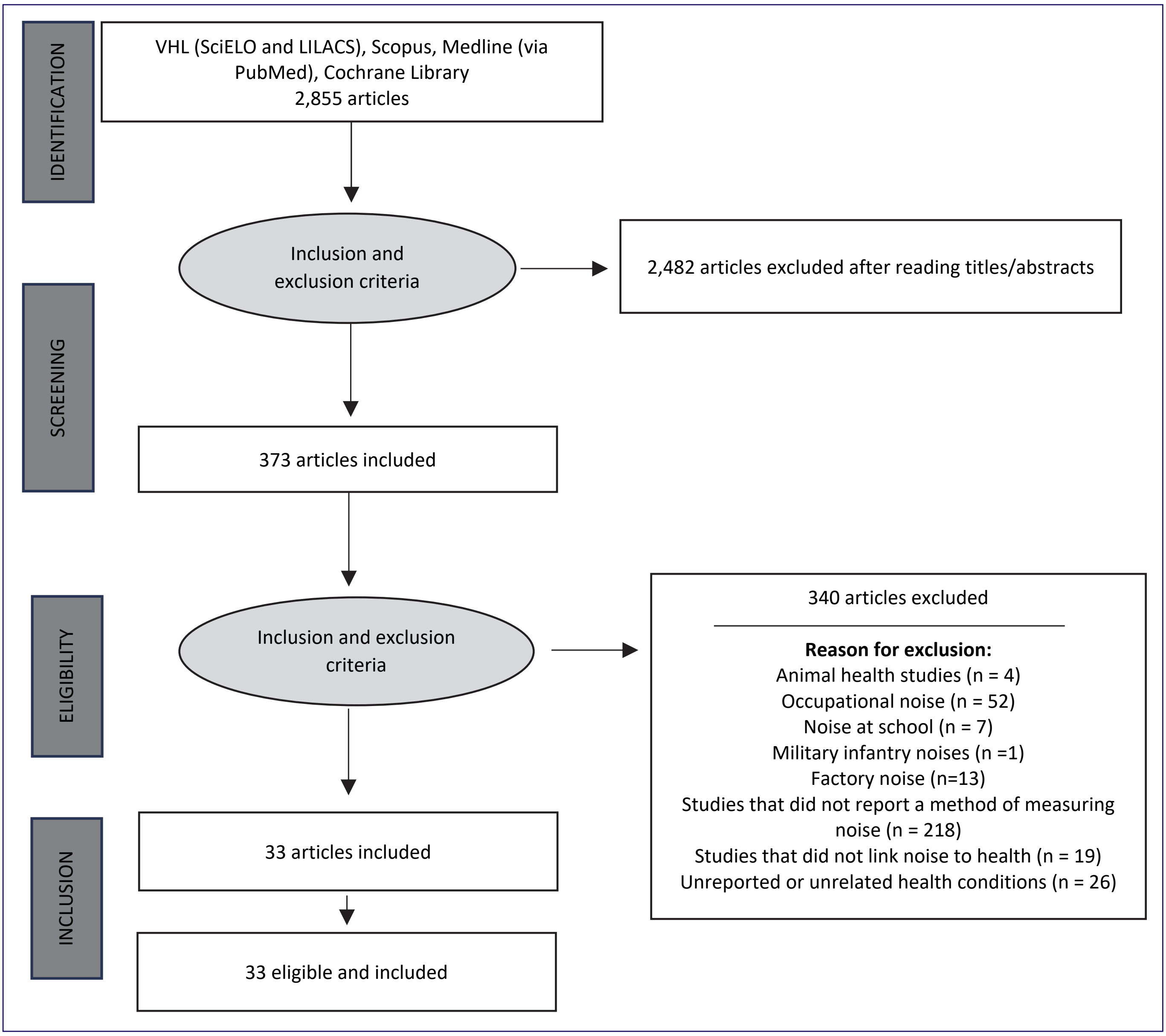

Figure 1. Review steps according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis – Extension for Scoping Reviews – (PRISMA-ScR)

five from the Cochrane Library[16-20], and 15 from Scopus[21-35]. The sample profile investigated in the articles ranged from the relationship between noisy areas and the effects on individuals living in their surro undings[7,8,11,13,16,19,22,25-27,29,33,34,36-39] to those who surveyed the entire city or a representative sample[34,35]. Other articles measured noise and directly interviewed the population[21,25,28,31,34,38].

Considering that noise is a global health problem, we chose to present the evidence by continent. Thus, we found that 18 (54.5%) studies originated in Europe[9,10,14,15,17,22-24,27-29,31,32,39], eight (24.2%) in South America[7,8,11-13,36-38], five (12.1%) in Asia[10,18,23,29,38], two (6%) in North America[33,37], and one (3%) in Oceania[36]. Table 3 lists the 18 countries from which the articles were published. Moreover, most articles were published in English.

Regarding their study designs, one was a cohort study[34], five were systematic reviews[5,17,18,22,27], one was a narrative review[33], and one was a scoping review[23]. There were also three case-control studies[21,25,29],15 cross-sectional studies[7,8,22,24,26-29,33-39], two case studies[12,35], two dissertations[14,20], and one doctoral thesis[19]. Several reviewed studies used cross-sectional designs to investigate the relationships between urban noise and health[4,7,13,26,28,39]. This type of design is advantageous because it offers a broad overview and identifies associations between variables. However, it lacks outcomes that consider the determination of causal relationships, since noise exposure and health effects are assessed simultaneously, without the longitudinal follow-up necessary to determine how cumulative exposure affects health over time. Nonetheless, these studies identified significant associations between high noise levels and the incidence of problems such as sleep disorders and cardiovascular disease, although with limited conclusions in terms of causality due to their cross-sectional design.

In contrast, the systematic reviews and meta-analyses included in this article allow for a more robust analysis by bringing together evidence from multiple studies on the impact of urban noise. These reviews broaden understanding of the topic, offering an overview of the negative effects of noise in different contexts and populations. However, they face challenges related to the methodological heterogeneity of the reviewed studies, as each one used different measurement methods and noise ranges, making direct comparisons between results difficult.

Table 3. Number of publications by country

Continent	Country	no. of articles	Language	Authors
Asia	*	1	English	Gjestland, 2019[18]
	South Korea	1	English	Kim et al.,2014[29]
	India	1	English	Pande et al., 2012[38]
	Malaysia	1	English	Darius, Awang, Deros & Isamil, 2014[10]
	Japan	1	English	Kageyama, 2016[23]
North America	Canada	1	English	King, Roland-Mieszkowski, Jason & Rainham, 2012[37]
	United States	1	English	Muzel, Gori, Babisch & Basner, 2014[33]
South America	Brazil	8	Portuguese	Antas et al., 2014[16]; Suriano, Souza & Silva, 2015[11]; Forcetto, 2016[20]; Bressane et al., 2016[7]; De Brito, 2017[13]; Palma, 2018[14]; Santos, 2020[19];
	Chile	1	English	Alburquenque et al., 2020[4]
Europe	*	1	English	Gjestland, 2019[18]
	Germany	2	English	Schübert et al., 2019[5]; Hegewald et al., 2017[25]
	Austria	1	English	Lercher, Widmann & Thudium, 2014[32]
	Bulgaria	1	English	Dzhambov & Dimitrova, 2014[30]
	Czech Republic	3	English/Czech	Franek et al., 2018[21]; Filová, Samaonhýl & Argalásová, 2015[27]; Urban & Máca, 2013[35];
	Spain	2	English/Spanish	Escobar & Divisón, 2016[39]; Foraster et al., 2014[31]
	England	2	English	Erfanian, Mitchell, Kang & Aletta, 2019[22]; Stansfeld, 2015[17];
	Switzerland	2	English	Schaffer et al.,2021[6]; Héritier et al., 2014[34]
	Poland	1	English	Nowakowska-kotas, Pokryszko-Dragan & Brodowski, 2015[28];
	Portugal	2	English	De Paiva Vianna, Alves & Rodrigues, 2015[26]; Silva & Mendes, 2012[12]
	United Kingdom	1	English	Thompson et al., 2022[24]
Oceania	New Zealand	1	English	Welch, Sheperd, Dirks, McBride & Marsh, 2013[36]
Total		33		

*The study evaluated 11 airports located in cities in Europe and Asia (Amsterdam, Athens, Berlin, Heathrow, Milan, Stockholm, Zurich, Ho Chi Minh City, Hanoi, Da Nang, Frankfurt).

Summary of results

Noise measurement procedures varied between articles. A temporal analysis reveals that articles published between 2012 and 2014[8,19,33-35] were concerned with establishing noise measurements from measuring devices. However, other articles published throughout 2014 had measurement methods using devices associated with logarithmic scales for predicting urban noise[33,34]. This is also reproduced in later years, such as 2015[26,27] and 2016[23]. There was also a concern on the part of researchers throughout 2014 in analyzing the regulatory standards for tolerance and emission of urban noise in countries[25,27-29]. These researchers describe in their articles a parallel between the effectiveness of the standards and the reality of cities.

The measured urban noise levels varied. Moreover, the measured values were above the determined limits in the articles that cited regulatory standards for urban noise emissions and tolerance[11,30,31,36]. The maximum values obtained in these articles were 56.7dB[31], 60 to 80 dB[30], 65 to 70 dB(A)[11], and 55 to 65 dB[36]. Other articles pointed out more intense values of urban noise, such as 85.8 dB[10] on a highway connecting Paka, Dungun, and Terengganu in Kuala Lumpur (Malaysia). Other articles obtained 93.3 dB[37] in a residential area in Canada. Another study found 94 dB[16] in the vicinity of a public market in João Pessoa (Brazil). Systematic reviews presented more intense values ranging from 96.5 dB[24] to 120 dB[27]. A study investigated the noise produced by drones and reported noise measurements of up to 102.6 dB, highlighting that drone noise was substantially more bothersome than traffic noise[24]. Research conducted in South Korea observed noise levels of up to 100 dB in high-exposure areas. The study reported sleep disturbances because of the noise[29].

Chart 1 describes all the articles and data collected for this scoping review, whereas Chart 2 presents the evidence from gray literature. In most studies, the relationship between the effects of noise on human health was assessed using semi-structured questionnaires.[7,11,16,18,19,21,38], prediction/inference of the impact of urban noise on human health[4,13], and by applying questionnaires concomitantly with physical and blood tests after noise exposure[32].

The consequences of noise on human health varied depending on the purpose of each research project. Thus, some authors concluded that there is a significant effect on cognitive impairment, reading ability, language, and executive function[24]. Another author found that drone noise is substantially more bothersome[6] than other noises. Noise levels obtained by researchers in Santiago, Chile, revealed associations between noise exposure and sleep disturbances, risk of cardiovascular disease, interference with daily activities, anger, displeasure, exhaustion, and stress.[4]. In Brazil, research has shown an association between noise exposure and discomfort, displeasure[19], discomfort[11], interference with work activity, tinnitus, headache, stress, lack of concentration, irritability[16], malaise, stress, reduced physical performance[7], negative effects on the overall health[13], discomfort, irritability[14], and hearing loss[20]. Other studies have highlighted other symptoms associated with exposure to high noise levels, such as hyperactivity/inattention[5]. A qualitative systematic review of five articles points to effects such as sympathetic arousal, increased respiratory rate, and perceptual variations in response to noise[22]. A case-control study of students revealed that traffic noise can increase walking speed, suggesting an environmentally stimulated stress response[21]. Another case-control study of women near Frankfurt Airport suggests an association between aircraft engine noise and the risk of breast cancer[25].

Chart 1. Data collection form – main findings of selected articles

Author and Year	Sample	Country	Publication language	Study design	Measurement procedures	Levels measured	Health consequences highlighted by the article
Thompson et al., 2022[24]	Systematic review with meta-analysis of 16 studies focusing on the relationship between noise pollution and human cognition	United Kingdom	English	Systematic Review with Meta-Analysis	Different noise measures were identified in the 16 studies	Values between 59 dB and 96.5 dB	Negative Effects/Impacts: on cognitive functions in children and older adults. Cognitive impairment, reading and language skills, as well as adverse effects on executive function.
Shäffer et al., 2021[6]	Systematic review without meta-analysis on noise emitted by drones and its effects on humans.	Switzerland	English	Systematic review	Different ways of measuring noise in the 10 references reviewed.	Values between 54 dB and 102.6 dB	Negative Effects/Impacts: Mood; Discomfort.
Alburquenque et al., 2020[4]	Two neighborhoods of Santiago	Chile	English	Cross-sectional	First location: Monitored 13 consecutive days in 2008. Second location: Monitored 35 days Noise recorded using Norsonic (Nor121 and Nor1225 external microphone)	First location: Minimum: 60.2 dB Maximum: 70.5 dB Second location: Minimum: 61.2 dB Maximum: 74.0 dB	Negative Effects/Impacts: Sleep disturbances, high discomfort; risk of cardiovascular disease, interference with daily activities, anger, displeasure, exhaustion and stress.
Schubert et al., 2019[5]	Systematic analysis of 14 articles	Germany	English	Systematic Review with Meta-Analysis	Systematic review with meta-analysis of 14 articles. Quantitative analysis of the reviewed articles.	Noise values from 40 dB	Negative Effects/Impacts: Hyperactivity/Inattention.
Erfanian, Mitchell, Kang & Aletta, 2019[22]	Qualitative analysis of 5 articles	England	English	Systematic review	Systematic review of 5 articles. Qualitative analysis of the impact of noise on the perception and psychological health of individuals.	Identified Values Reference 1: 52.2 – 77.5 dB. Reference 2: 40 – 80 dB. Reference 3: 71 dB. Reference 4: 60 – 74 dB. Reference 5: 64 dB.	Reference 1 Sympathetic arousal Reference 2 Increased respiratory rate. Reference 3 No change in heart rate was found. Reference 4 Increased heart and respiratory rate. Reference 5 Substantial variability in the mean sound perception response. Natural sounds provoked pleasure and arousal. Noise pollution was considered dominant and agitating.
Franek et al., 2018[21]	83 students Ages 19-25 years 48 men 35 women	Czech Republic	English	Case-Control	It obtained measures from secondary data. Noise emission was monitored using digital devices in the headphones of the study groups.	Paths 1 to 4: 55 dB(A) to 60 dB(A). Paths 5 to 7: 50 dB(A) to 55 dB(A).	Negative Effects/Impacts: Increased walking speed in the case group compared to the control group. Suggests an environmentally stimulated stress response.
Gjestland, 2018[18]	Review of evidence from 12 studies	Airports in 11 cities in Europe and Asia	English	Systematic review	It mentions different methods, without specifying them.	Noises ranging from: 54.6 dB – 75.5 dB	Negative Effects/Impacts: High irritability; moderate quality of life.
de Brito, 2017[13]	Capivari neighborhood, in the tourist resort of Campos do Jordão	Brazil	Portuguese	Cross-sectional	Assessments at 15 locations, 8 measurements lasting 15 minutes. Type II sound pressure meter with "A" compensation circuit.	Weekdays – 70 dB(A) Holidays – 60 dB(A)	Negative effects/impacts: worsening health and quality of life.
Hegewald et al., 2017[25]	571,183 women living in the vicinity of Frankfurt International Airport	Germany	English	Case-Control	Traffic noise values were obtained from data provided by municipalities. All noise values were calculated according to German standards using SoundPLAN version 7.3 software.	Noise levels from air and rail transportation > 40 dB. Values ranged from <40 dB for aircraft engines to 85.7 dB for ground traffic.	Negative Effects/Impacts: Increased risk of estrogen receptor (-) breast cancer.

Author and Year	Sample	Country	Publication language	Study design	Measurement procedures	Levels measured	Health consequences highlighted by the article
Bressane et al., 2016[7]	Downtown Rio Claro, São Paulo. 109 individuals interviewed	Brazil	Portuguese	Cross-sectional	Measurements were taken at 35 points. Used an Instrutherm digital sound pressure meter, model DEC-470, Class 2 (Instrutherm, São Paulo, Brazil). Measurements were taken on Thursdays and Saturdays from 8:00 AM to 9:00 AM, 11:00 AM to 12:00 PM, 12:00 PM to 1:00 PM, 2:30 PM to 3:30 PM (Saturday only), 5:00 PM to 6:00 PM, and 6:00 PM to 7:00 PM.	Values around 70 dB(A) were obtained	Negative Effects/Impacts: 66.4% reported that noise pollution has had some impact on their health; 34.4% reported effects on their mood and physical performance; 73% reported stress due to noise; 71.5% reported effects of noise pollution on mental performance; 77% reported hearing and communication impairments.
Kageyama, 2016[23]	Urban zones	Japan	English	Scoping review	Predictive logarithmic scales considering the level of continuous and intermittent noise during dusk and night.	Average values of 40 dB were recorded. Variations of 10-15 dB depending on the opening or closing of the house's windows.	Negative Effects/Impacts: sleep disturbance.
Escobar & Divisón, 2015[39]	London population. Analysis of medical records of patients hospitalized for cardiovascular causes and cardiovascular mortality.	Spain	Spanish	Cross-sectional	Annual road traffic noise levels for the years 2003-2010 were modeled at the geometric centers of 190,000 zip code locations using the TRAffic. EXposure (TRANEX)2 noise model with a noise level resolution of 0.1 dB(A).	Values > 60 dB(A)	Negative effects/impacts: ischemic heart disease; increased mortality rate.
De Paiva Vianna, Alves & Rodrigues, 2015[26]	Exploratory study conducted in Porto (Portugal)	Portugal	English	Cross-sectional	The soundscape was made based on the calculation methods of the Lden and Ln indicators. The highway noise prediction was made using NMPB-Routes-96, with the support of the Cadna-A software.	Noise levels: 48.5 dB(A); 52.6 dB(A); 57.8 dB(A); 63.3 dB(A); 67.5 dB(A); 72.8 dB(A).	Negative Effects/Impacts: 70 to 85% reported no discomfort between 48.5 and 63.3 dB(A); 35% reported some discomfort at 67.5 dB(A); 75% reported severe discomfort at 72.8 dB(A).
Filová, Samonhýl & Argalásová, 2015[27]	Literature review	Czech Republic	Czech	Literature review	Different measures and ways to measure noise. Logarithmic scales considering the WHO safety standard of 55 dB and frequencies from 2 to 6 kHz.	Values ranging from 50 dB to 70 dB and up to 120 dB.	Negative Effects/Impacts: discomfort, sleep disturbance, changes in cognitive functions and the cardiovascular system.
Nowakowska-Kotas, Pokryszko-Dragan & Brodowski, 2015[28]	Study with 36 healthy volunteers in the city of Wroclaw	Poland	English	Cross-sectional	Traffic noise was measured using a microphone with a preamplifier (PCB model 378B02, PCB Piezotronics Inc., USA).	The noise level ranged from 45 to 85 dB	Negative Effects/Impacts: Deterioration in cerebral blood flow during mental activities. The non-dominant hemisphere appears to become more involved in processing auditory signals under adverse conditions.
Stansfeld, 2015[17]	Narrative review of 25 articles	England	English	Systematic review	Articles described various measurement methods and instruments, fixed measurement points, decibel meters, and dosimeters.	From 55 dB to 65 dB	Negative Effect/Impact: cardiovascular problems; changes in cognition and mental health and blood pressure problems.
Suriano, Souza & Silva, 2015[11]	Three avenues in the municipality of São Carlos, São Paulo	Brazil	Portuguese	Cross-sectional	The study used a Brüel&Kjær Analyser 2270-L handheld device, with a windshield attached to the microphone to minimize interference. It was configured to meet the specifications for external environmental noise measurements, meeting the methodological specifications indicated by NBR 10.151.	Morning: 65 and 70 dB(A) Evening: 60 and 65 dB(A)	Negative Effect/Impact: noise discomfort.
Antas et al., 2014[16]	Noise assessment in the vicinity of the João Pessoa/PB public market - 23 establishments - 89 workers	Brazil	Portuguese	Cross-sectional	Sound pressure measurement using a digital decibel meter (Minipa), at the entrance of each establishment.	Values ranged from: 55 dB to 94 dB	Negative Effects/Impacts: Discomfort, interference with work activities; Auditory Complaints: Tinnitus. Non-auditory Complaints: Headache, stress, anxiety, lack of concentration, irritability.

Author and Year	Sample	Country	Publication language	Study design	Measurement procedures	Levels measured	Health consequences highlighted by the article
Kim et al., 2014[29]	Evaluation of regions surrounding a military airfield. Divided into 3 groups: 1 high exposure; 2 low exposure; 3 control groups.	South Korea	English	Case-control	Average aircraft noise levels when landing, using NL-20 and NL-21 sound meters, following the recommendations of the Korean Ministry of Environment. Sound levels were recorded for 7 days. Maximum, average, and minimum measurements were obtained.	Values varied, being higher in 4 areas: 100 dB, 95 dB, 85 dB and 75 dB, respectively.	Effects/Negative impact: sleep disorders.
Darius, Awang, Deros & Isamil, 2014[10]	Highway from Paka to Dungun Terengganu. Kuala Lumpur	Malaysia	English	Cross-sectional	Measurements were made at 6 stations, performing subjective evaluations. The first measure was taken less than 50 meters from the sound source. A SoundTrack LXt sound level meter was used. The device was calibrated and installed 1.2 to 1.5 meters away and 1 meter from the highway. Each measurement lasted 40 minutes.	Values ranged from 51 dB to 85.8 dB	Negative effects/impacts: emotional disorder (31.6%), insomnia (28.9%), general health problems (29.8%).
Dzhambov & Dimitrova, 2014[30]	30 individuals residing in a neighborhood of Plovdiv, Bulgaria.	Bulgaria	English	Cross-sectional	The French National Method "NMPB-Routes-96" was used with the Bruel sound level measuring device on the Kjaer Typer 2240. The measurement took place within a radius of 600 meters.	Values ranged from 60 dB to 80 dB.	Negative Effects/Impacts: Irritability/anger strongly associated with continued noise exposure.
Foraster et al., 2014[31]	The sample consisted of 2,067 individuals aged 36-82 years from Barcelona.	Spain	English	Cross-sectional	The researchers followed the European Noise Directive 2002/49/EC (END) model, which uses the NMPB routes-96 method. Measurements were taken with an SC-30 sound meter and a CB-5 calibrator. Measurements were taken outside and inside the home.	External measurement values: 56.7 dB; 53.5 dB; and 27.1 dB. Internal measurement values: 57.2 dB.	Negative effects/impacts: prevalence of hypertension.
Lecher, Widmann & Thudium, 2014[32]	40 km Lower Inn valley (east of Innsbruck).	Austria	English	Cross-sectional	Measurements carried out according to Austrian Guidelines (OAL Nr. 28 + 30, ONORM S 5011) with a resolution of 25 m x 25 m.	Values between 45 dB and 75 dB	Negative Effects/Impacts: on the cardiovascular system, Hypotension and increased reported use of medication.
Muzel, Gori, Babisch & Basner, 2014[33]	Literature review focusing on cardiovascular outcomes.	United States	English	Narrative review	Different methods presented by the studies. Estimates, predictive logarithmic scales based on defined levels.	Values start at 33 dB. Values above 70 dB are cited.	Negative Effects/Impacts: Increased prevalence of high blood pressure and incidence of cardiovascular disease.
Héritier et al., 2014[34]	4,000 randomly selected residents, aged 30 to 60 years, in the cities of Basel and Basel-Country. They were followed for 1 year.	Switzerland	English	Cohort study	The noise values were obtained using a model established in 2008. The noise levels are obtained using calculations based on a logarithmic scale from the SonBase Model values.	Values ranged from 52.02 dB(A) to 58.18 dB(A) on the highway. Values on the railway ranged from 23.59 dB(A) to 34.03 dB(A).	Negative Effects/Impacts: Sleep disturbances and discomfort.
Urban & Máca, 2013[35]	Five cities in the Czech Republic	Czech Republic	English	Cross-sectional	The authors used noise meters for 24 hours. Participants provided annoyance measurements through simple questions.	Values ranged from 47 to 79 dB on highways. Values ranged from 46 to 72 dB on the railway network.	Negative Effects/Impacts: on overall satisfaction with life in urban areas; noise nuisance due to highways and railways has a strong negative effect on residential satisfaction.
Welch, Sheperd, Dirks, McBride & Marsh, 2013[36]	Five areas in Auckland	New Zealand	English	Cross-sectional	Estimated sound levels based on the New Zealand Transport Audit. West = 61 dB; South = 50 dB; North = 77 dB; East = 75 dB	Estimated values ranging from 55 to 65 dB.	Negative effects/impacts: on the quality of life.

Author and Year	Sample	Country	Publication language	Study design	Measurement procedures	Levels measured	Health consequences highlighted by the article
King; Roland-Mieszkowski; Jason & Rainham, 2012[37]	Two neighborhoods: One exclusively residential and the other residential and commercial. Area 1: 653 individuals Area 2: 566 individuals	Canada	English	Cross-sectional	Sound level measurements were performed using a Center 322 Logging Sound Level Meter (SLM) instrument and a Marantz PMD-660 Solid State recorder.	Area 1 – average of 48.1 dB(A); Maximum values ranging from 60.6 dB(A) to 93.3 dB(A) Area 2 – average of 56.6 dB(A); Maximum values ranging from 69.7 dB to 90.3 dB(A).	Negative Effects/Impacts: increased blood pressure; sleep quality; quality of life; cognitive performance; hormonal balance (epinephrine levels).
Pande et al., 2012[38]	602 individuals.	India	English	Cross-sectional	Measurements taken during quiet and noisy periods. The authors developed software that estimates noise levels.	The environmental sound level was classified as high and very high (70 dB – 110 dB) according to the Noise Guidelines Manual 1995	Negative Effects/Impacts: on memory and difficulty in determining the short-term impacts of noise exposure.
Silva & Mendes, 2012[12]	Assessment of air and noise pollution in the city of Viana do Castelo – Portugal.	Portugal	English	Case study	Traffic Noise Prediction Method – 96. Calculates the acoustics of each emission range by a receiver that intersects a source line.	Values ranged from 45 dB to 65 dB.	Negative Effects/Impacts: on human health in general.

Chart 2. Data collection form with main findings

Author and Year	Sample	Country	Publication language	Characteristics of evidence	Measurement Procedure	Levels measured	Health consequences highlighted by the article
Santos, 2020[19]	Border garden of the School of Public Health – West Zone of São Paulo/SP	Brazil	Portuguese	Doctoral thesis	The author reports having used an integrating sound pressure meter, model SOLO, class 1. In situ assessment, route traced and measurements taken at 3 points.	Point 1 = 72.7 dB(A) Point 2 = 94.2 dB(A) Point 3 = 76.9 dB(A)	Discomfort and displeasure.
Palma, 2018[14]	Tietê Riverbank, Tietê Arch – São Paulo - SP	Brazil	Portuguese	Master's dissertation	The author reported using a sound level meter, model 971 type 1 - SVANTEK Measurements performed in accordance with NBR 10.51/2003	Values above 70 dB(A) were found.	The interviewees reported discomfort and irritability in relation to the noise.
Forcetto, 2016[20]	Two locations in the ABC Paulista region of São Paulo, SP. Motorcycle exhaust system evaluation	Brazil	Portuguese	Master's dissertation	The author reported that two devices were used to measure the noise: -MNS Bruel & Kjaer – model 2238 Mediator -Bruel Kjaer Acoustic Calibrator model 4231 – 94 dB-SPL 1000 Hz	It reports maximum values of 80 dB(A)	It is important to note that this noise level can cause hearing loss in the motorcyclist and discomfort in nearby individuals.

Summary of evidence

This review aimed to analyze the main evidence that measured urban noise and established the relationship between the identified noise levels and the effects on human health. Because this is a scoping review, it analyzed the methodologies employed in the reviewed studies and the methods of measuring urban noise. Such analyses can establish critical reasoning regarding the methods of noise measurement and analysis, noise levels, and their effects/impacts on human health. The articles collected in this review express scientific concern in understanding the phenomena of illness related to urban noise. None of these articles addressed speech perception difficulties or categorized the sample into hearing and non-hearing individuals.

Identifying urban noise is important for establishing noise prevention and control measures. This action needs to be carried out in a standardized manner, considering the physical nature of the noise and its source. In this review, many of the methods of research that investigated field noise met this prerogative[7,8,11,13,21,24-26,32,34,36-38]. It is noteworthy that urban noise measurements were taken on streets and highways, during periods of heavy traffic, as well as during quiet periods. In other studies, authors compared values measured in outdoor and indoor environments of homes. These strategies have important applications for characterizing the sources and levels of urban noise, areas of greater or lesser acoustic contamination, and population exposure. This brings scientific evidence closer to the reality to which individuals are exposed. The study subjects varied in age, sex, and nationality, with the majority being adults with no apparent or reported health conditions[16,21,25,26,28,30,31,37,38]. These characteristics align with the objectives of the studies contained in this review.

The urban noise levels found and described in the reviewed articles were, for the most part, above the values established as acceptable by both the World Health Organization (WHO) and the laws and regulations of their respective countries[11,13,16,19,21,39]. The WHO specifies that the sound pressure level should not exceed 50 dB $L_{Aeq\ 16\ hour}$ in outdoor areas during the day and 30 dB $L_{Aeq\ 8\ hour}$ in areas outside the bedroom at night[18]. According to the WHO, noise exposure levels that do not harm quality of life and health are 55 dB(A), being reduced to 45 dB(A) during sleep. The WHO also points out that values above 65 dB(A) can have negative effects[11].In Brazil, NBR 10.151 establishes the equivalent sound pressure level (LA_{eq}) in decibels weighted in dB(A) and the daytime (from 7 am to 10 pm) and nighttime periods (from 10 pm to 7 am), limiting the values to 55 dB and 50 dB respectively[40]. As a result, several health effects are described for the individuals studied. This review found evidence that noise levels above 80 dB promote hearing loss, tinnitus, discomfort, interference with work activities, headaches, stress, lack of concentration, and anxiety[16,20]. A literature review found an association between exposure to aircraft and traffic noise and the cognitive ability of attention in children[24]. Although auditory symptoms are the first to be noticed, subjective perception also deserves attention, as it impacts the individual's entire body. None of the studies included in this review mentioned the type or degree of hearing loss caused by urban noise.

Among the articles reviewed, some researchers analyzed the subjective aspects of urban noise perception and concluded that they are related to non-auditory effects[7,11,16]. These authors highlighted annoyance, discomfort, decline in mental performance, and irritability. A systematic review found declines in reading, speaking, and language skills. The authors describe the relationship between worsening reading performance and distraction caused by aircraft noise, whose measured noise level was 60 dB LAeq[24]. Urban noise also had negative effects on quality of life[13,18], quality of sleep[4,10,23,27,29,34], and cardiovascular health[17,22,27,33,39]. A systematic review identified an increase in heart rate associated with exposure to high noise levels, specifically the sound of sirens. Using regression analysis, the authors established this relationship and highlighted that the observed impact on heart rate was equivalent to that recorded during physical activities, such as tennis[22]. The literature indicates that, in addition to these signs, increased systolic and diastolic blood pressure causes the release of stress hormones, such as catecholamines and glucocorticoids[22]. Additionally, high noise levels have been associated with other cardiovascular symptoms, including hypertension, ischemic cardiovascular disease, and heart attack[39].

This evidence supports health authorities' concerns about rising urban noise levels. It's plausible to hypothesize that these effects may culminate in an increased prevalence of medication use to regulate blood pressure, sleep, and concentration. This could impact public and private health systems. Preventive measures must be discussed with society, and further studies must investigate the socio-interactional and health system impacts of urban noise.

Examples of current Brazilian legislation include CONAMA Resolution No. 001, of March 3, 1990, which established the National Program for Education and Control of Noise Pollution – Silence[40], and ABNT Standards No. 10.151 and 10.152. Even so, this review found that noise levels exceed the standards in this country[7,11,13,14,16,20]. This evidence once again reinforces the need to discuss this issue with society and government sectors involved with infrastructure and urban planning.

Methods for measuring urban noise and its relationship with human health

Some authors have considered factors such as location and time of day[26,36-38] when measuring noise. Most of this consideration is related to the fact that traffic flow is the most prevalent source of urban noise in studies. Other authors have predicted urban noise using logarithmic scales[23,33,34]. This methodology proved to be more specific, and although they did not justify choosing this method, it is known that the logarithmic scale represents large variations in sound intensity more understandably and practically. Some authors have specified the use of the L_{Aeq}, justifying it by the fact that this scale is often used to summarize sound levels over a given period. Other authors have also pointed out that this scale is more accurate[11,23]. These same authors pointed to the evidence that community noise at night is more dangerous than during the day, and proposed the scales $L_{Aeq,dn}$ and $L_{Aeq,den}$, in which the noise descriptors refer to the day (d) and evening (e). Other authors also considered the specificity of noise during the measurement periods; they proposed the scales L_{den} and L_n to calculate noise activity in urban spaces[26]. A review article highlighted the evidence that supported the WHO in developing a guideline that recommends the logarithmic limit of 45 dB L_{den} to avoid adverse health effects from aircraft[18]. The human ear perceives sound logarithmically, making this scale more suitable for assessing the effect of noise on human perception and health. Other researchers have used previously established values of urban noise levels in the study sites as a basis and then used logarithmic scales[26,27] to predict the effects of noise. This demonstrates organizational progress in these countries, as it indicates that the infrastructure and urban planning sectors have characterized regions and zones through direct noise measurements.

The methodology for measuring urban noise is established and published in some countries, such as Austria with the Austrian Guidelines[32], Bulgaria with the French National Method (NMPB-Routes-96)[30], Spain with the European Noise Directive 2002/49EC (END)[31], which uses the Traffic Noise Prediction Method-96, and Portugal with the Traffic Noise Prediction Method-96[12]. These instruments demonstrate that these European countries have long investigated and been concerned about urban noise. In Brazil, there is current legislation that limits and promotes the control of noise pollution[40], in addition to ABNT Standards No. 10.151 and 10.152, which reflect awareness of the harm caused by urban noise and efforts to address its effects. This information is relevant because the physical characteristics of noise and its source require measurement precision and criteria.

The measurement methods presented in the studies compiled in this review are reproducible, and the urban noise levels identified demonstrate the accuracy of the methods employed, given the symptoms reported by all interviewees. Most authors also highlight the devices and techniques used to measure urban noise. It is important to emphasize that there was a wide variability in the devices used; however, the description of the techniques employed stood out most among the articles[7,8,11-13,24,26,28,34,36-38]. It should be noted that the objectives of each study involved different measurement methods, positions, times, and periods. The characteristics of the measurement devices also varied, from portable (hand-held) devices with a windshield attached to the microphone[11], to a sound level meter attached to an external microphone[4], a sound level meter (SLM)[20], Type 1 sound level meter with octave bands, sound level calibrator specifications ANCI S1.40-1984 and IEC 942:1998 Class 1. Frequency: 1000 Hz. Amplitude: 114 dB[14], digital sound pressure meter (decibel meter)[7,16] and a Type II sound pressure meter with "A" compensation circuit and fast response[13]. Only one systematic review presented details on the noise measurement devices; these studies included 22 microphones, an intensity probe, and a hemispherical measuring surface[6]. However, we believe that the diversity of devices and the lack of information on calibration and measurement accuracy may have somehow influenced the study results. The articles established the relationship between the effects of urban noise and human health through interviews and questionnaires. This methodology is practical, inexpensive, and quick; however, it may not fully reflect the reality of these effects on the part of the interviewee, as in those studies that inferred the effects of urban noise on health based on predictive models. It is imperative to consider the development of other study methodologies to reduce biases in data collection.

The effects of urban noise are not uniform, varying according to socioeconomic and cultural factors and geographic conditions. The study conducted in the neighborhoods of Santiago, Chile[4], and the study conducted in Campos do Jordão, São Paulo, Brazil, demonstrate variations in the levels of discomfort and health in regions with different characteristics. These differences highlight the need for local policies adapted to each reality, considering population density, urban activity patterns, and the resources available to mitigate the effects of noise. In densely populated urban areas, such as large metropolises, the concentration of vehicles, commercial, and industrial activities contributes to higher and more persistent noise levels. Some studies show that neighborhoods with high urban traffic tend to have higher noise levels, negatively impacting residents' quality of life[4,14]. Increased discomfort and health problems, such as stress and sleep disorders, are especially common in these regions due to continuous exposure to noise above 60 dB, which exceeds the limits considered safe for health.

The effects of urban noise can be even more severe in lower-income communities, where there are fewer resources for investment in soundproofing infrastructure and less access to quiet areas. A study conducted in Capivari, Campos do Jordão[13], found that lower-income populations generally reside in areas closer to sources of intense noise and are less subject to regulatory interventions. These communities may face considerable risks of cardiovascular and mental health problems due to prolonged exposure to noise without the possibility of mitigation through adequate structures[22]. Cultural factors also influence how noise is perceived and how it affects individuals. In areas with a more tolerant culture of coexistence regarding noise, such as certain metropolitan regions, residents may report less subjective discomfort, although the effects on physical health are still present. Conversely, in countries like Switzerland, where noise standards are stricter and residents are accustomed to quieter environments, even small increases in noise levels are perceived as a nuisance, as noted in a survey[6].

The influence of climate and geography must be considered, as these factors can amplify or reduce the effects of noise. In areas with high temperatures, it's common for people to keep windows open for longer periods, which can increase exposure to external noise. On the other hand, in more mountainous regions, sound tends to reverberate, intensifying the sensation of discomfort. A study conducted in specific areas located in mountainous regions of Kuala Lumpur[10] indicates that traffic noise can propagate more intensely, affecting residents' quality of life and well-being.

Advances and Recommendations

A range of interventions can be considered to reduce urban noise. Although the included articles do not present noise prevention strategies, the literature shows that measures such as installing noise barriers in high-traffic areas and creating quiet zones in residential neighborhoods are effective strategies in many cities. Additionally, real-time monitoring can allow for rapid adjustments in urban noise levels. These solutions, combined with public awareness and rigorous monitoring of traffic noise, can offer significant improvements in the population's quality of life and health. In some European cities, strict noise control policies, such as those following the European Noise Directive, offer additional protection to the population by imposing maximum limits and encouraging quiet zones. This contrasts with areas in countries with less regulation, where noise levels are less controlled and the population is more exposed. A study comparing airports in cities in Europe and Asia[2] highlights that differences in regulations and public policies are a determining factor in the variation in quality of life and the incidence of health problems in different regions.

Limitations

Despite the high level of criteria used in identifying the selected articles and the fact that the search followed strategies suggested in the literature, many studies were still discarded. Most retrieved articles were cross-sectional, a study design that does not allow for generalization of the results. Therefore, even if further reviews are conducted, it is plausible to encourage other study designs within this topic to understand the long-term effects of urban noise and the effectiveness of prevention measures.

Not all reviewed articles pointed out their limitations, whereas those that did highlighted the influence of the context in which noise perception was collected on the results[4], and difficulty in mapping noise by street[11]. Among the systematic reviews, the scarcity of research by period was the most prevalent limitation[6,22,24,25]. Another article highlighted the relatively low level of evidence in its results[39]. None of the reviewed articles reported interference factors between the measurement equipment and the results.

It is worth noting that the evidence found in this review highlights the importance of analyzing the effects of urban noise on human health. Likewise, this review highlights the need for health and public infrastructure sectors to establish science-based actions and prevent health problems demonstrated by previously published evidence. Therefore, this review serves as a foundational tool for recognition and a starting point for decision-making.

CONCLUSION

The results of this review highlight the growing interest of researchers in exploring the non-auditory effects of urban noise on human health. The articles selected for this review presented diverse noise measurement methods, all of which were based on scientific evidence and the current regulations of their respective countries. The use of the logarithmic scale has increased in recent years in the articles selected for this review. Establishing the relationship between urban noise and its effects on human health was mostly done through questionnaires and prediction models or by inference – i.e., the most prevalent effects of urban noise on human health in this review were supported in an unobjective manner. This evidence reinforces the concern of researchers and health authorities in addressing noise, advocating for and implementing preventive measures. Furthermore, the development and validation of reliable instruments to measure individuals' perception of noise is imperative.

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Authors' contributions:

TCP: Conceptualization; Data curation; Data analysis; Investigation; Methodology; Writing - Original draft; Writing - Review & editing.

RCLS: Conceptualization; Data curation; Data analysis; Investigation; Writing - Original draft.

SASC, SMAL: Conceptualization; Data curation; Data analysis; Investigation; Methodology; Writing - Review & editing.

AALF: Conceptualization; Data curation; Data analysis; Investigation; Methodology; Project administration; Supervision; Writing - Original draft; Writing - Review & editing.

Data Sharing Statement:

All data collected in this review will be made available immediately after publication, along with the research protocol, which will remain accessible indefinitely to researchers who present methodologically sound proposals.