

Review

# Soundscape Research in Streets: A Scoping Review

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**Abstract:** Streets play a crucial role in shaping urban soundscapes, influencing individual wellbeing and urban sustainability. Although urban soundscapes have been widely studied, research focusing on street soundscapes remains limited. This scoping review aims to provide a comprehensive analysis of the main themes and methodologies used in recent street soundscape literature. Scopus and ScienceDirect databases were searched for journal articles and conference papers with the keywords “street and sound”. The review included articles published in English between 2000 and 2025. The selected studies focused on soundscapes in outdoor environments while offering insights into streetscape features. Articles that did not focus on perception of the street environment or report a sample size were excluded, resulting in 16 studies in the final review. Soundscapes were mostly examined in terms of noise annoyance ( $n = 6$ ) and sound perception ( $n = 14$ ), distinguishing between pleasant and unpleasant sounds. Natural elements are frequently identified as essential streetscape ( $n = 8$ ) and soundscape components of streets ( $n = 3$ ). These features are associated with positive perceptions, whereas traffic features are perceived negatively. The predominant methodological approach was laboratory studies ( $n = 10$ ), with participant groups typically consisting of healthy adults. Sample sizes ranged from 10 to 1200. Overall, the literature points to a significant gap in research on the effect of street soundscapes on wellbeing, revealing that numerous streetscape characteristics remain unexplored and the link between soundscapes and street features has not been thoroughly examined.

**Keywords:** soundscape; streetscape; perception; street



Academic Editor: Siu-Kit Lau

Received: 12 February 2025

Revised: 3 April 2025

Accepted: 4 April 2025

Published: 9 April 2025

**Citation:** Ozturk, Z.S.; Kang, J.; Aletta, F. Soundscape Research in Streets: A Scoping Review. *Sustainability* **2025**, *17*, 3329. <https://doi.org/10.3390/su17083329>

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## 1. Introduction

Soundscape studies exploring how sound environments impact human experiences in cities have emerged as a significant and growing area within urban wellbeing and sustainability research. These studies have expanded our understanding of how individuals and communities perceive and interact with their acoustic surroundings. Initially, soundscape research focused on identifying and categorising sounds, evolving from the examination of noise as a nuisance to an appreciation of how diverse sounds can enhance wellbeing and contribute to urban life [1,2]. The field now embraces psychoacoustic elements, examining both the negative and positive impacts of sound on human health and behaviour in various urban contexts [3–7].

Historically, soundscape research has focused on urban public spaces such as parks, squares, and commercial districts [5,8–16]. These studies have investigated how natural sounds, social interactions, and urban activities shape auditory experiences in these settings [17–19]. For instance, research has often examined how factors like greenery, traffic,

and pedestrian movement influence sound perception and its effects on individuals' physiological and psychological states [18,19]. While such studies have contributed valuable insights into how people experience sound in these environments, they have largely overlooked the role of streets as a soundscape. Despite being among the most prominent public spaces in cities, streets remain underexplored in the soundscape literature.

Streets are a vital component of the urban fabric, functioning as spaces where daily life unfolds and diverse social, economic, and cultural activities take place [19]. As such, they shape not only the visual but also the auditory characteristics of the cities. Streets are home to a dynamic mix of sound sources, including human activity, vehicles, urban features and natural elements, all of which contribute to the overall urban soundscape [19,20]. These urban features help determine noise levels and annoyance in streets, as well as pedestrian perception [21,22]. Investigating the soundscape of streets is crucial because these spaces are integral to urban life and have the potential to influence both individual wellbeing and community cohesion [20,23–25]. Given their importance, understanding how street soundscapes affect urban residents and contribute to the broader acoustic environment warrants further investigation.

However, the current body of research on street soundscapes is sparse, with few studies specifically focusing on how streets are experienced acoustically. This gap in the literature presents an opportunity to systematically review existing studies on street soundscapes and examine how these environments have been investigated. This review will examine main methodologies, key variables, and participant samples in street soundscape research; we aim to provide a clearer picture of the current state of knowledge and highlight areas for future research.

**RQ1:** The primary research question of this study is to identify which soundscape features have been investigated in street soundscape contexts and which are under-represented.

In addition to this main question, there are two sub-research questions:

1. Which streetscape features have been most frequently examined in the street soundscape literature, and which are under-represented? (RQ2)
2. Which methodological approaches have been implemented in street soundscape studies? (RQ3)

This review seeks to synthesise existing findings, identify trends, and propose directions for further exploration in the field of urban and rural soundscapes, with a particular focus on streets.

## 2. Methods

The literature review focuses exclusively on peer-reviewed journal and conference papers in English. Scopus and ScienceDirect databases were searched for publications from January 2000 to March 2025 using keywords “soundscape” (“soundscape”, “sound perception”, “noise perception”), and terms related to “streets” (“streetscape”, “street”, or “road”). Studies were selected and filtered according to the PRISMA (Preferred Reporting Items for Scoping Reviews) guidelines for scoping reviews [26].

Inclusion criteria for selected studies are as follows:

- Focus on street soundscapes: The studies should address street soundscapes, not only from an acoustic perspective but also the perception of soundscapes in terms of various characteristics such as pleasantness, eventfulness, chaos, annoyance, or sound comfort.
- Investigation of streetscape features: The studies should include perceptions of visual street features, e.g., street furniture, vegetation, water features, lighting, and the effects of daily or seasonal changes.

- Focus on outdoor street spaces and determining sample size: The review is limited to studies investigating outdoor street environments. No specific street type (e.g., commercial streets, underground streets, or canyon streets) was targeted. The review encompasses all types of outdoor streets while excluding other public spaces. All selected studies must report the number of participants in the research.

### 3. Results

This study aims to review streetscape and soundscape perception studies between 2000 and 2025. At the end of the screening process, conferences ( $n = 3$ ) and journal articles ( $n = 13$ ) were extracted (see Figure 1).

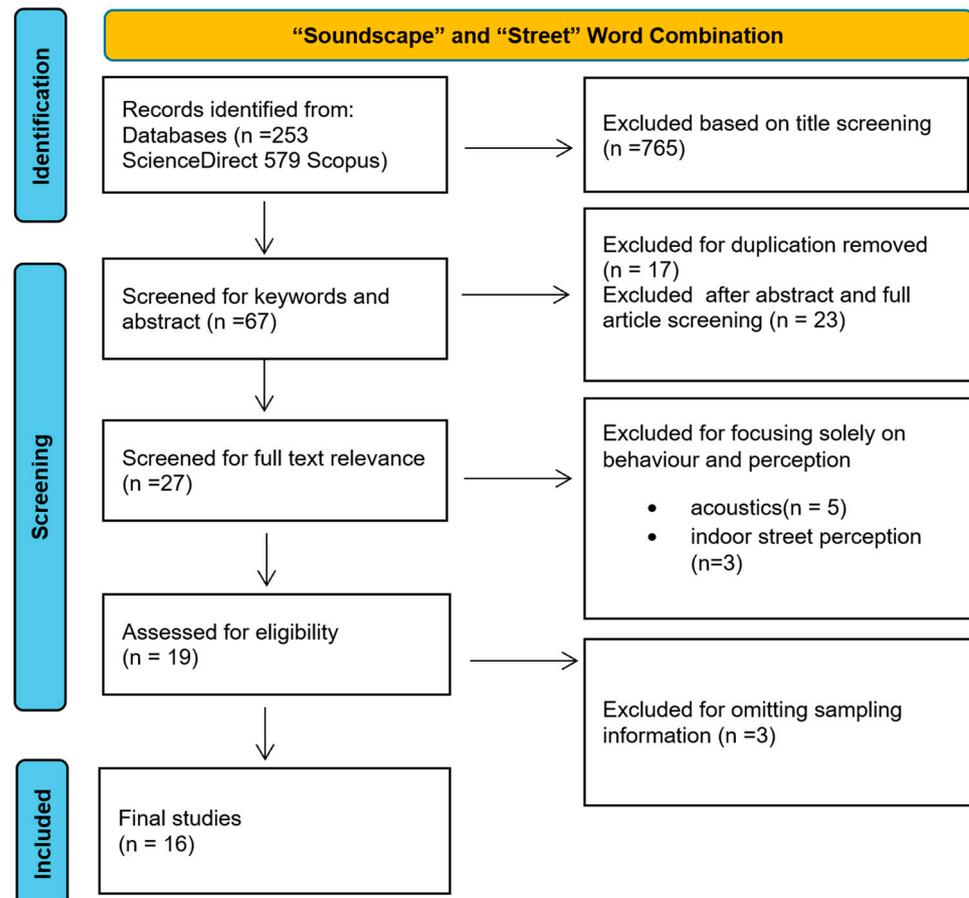


Figure 1. PRISMA flow diagram for the identification of studies via databases.

#### 3.1. Search Strategy and Selection Process

During the initial screening, sixty-seven articles were selected based on their titles. Seventeen of these were subsequently excluded due to duplication. An additional 765 studies were excluded because their full content did not meet the specified inclusion criteria, and 23 studies were eliminated since they did not focus on perception and soundscape directly. Most of the excluded research focused on public spaces, such as squares, parks, and residential areas, rather than the street environment. Some of these studies also lacked coverage of the soundscape (e.g., perception of sound environment) and instead concentrated on sound measurements. Two studies were excluded because they did not report the sample size, while three others were excluded because they did not focus on outdoor streets or did not mention the sample size. In total, sixteen studies were included in the review. Two reviewers evaluated the chosen articles regarding the inclusion criteria to minimise bias in the study selection. Figure 1 depicts the review's screening process.

### 3.2. Included Studies

Study 1 [27]: The influence of natural features and height-to-width ratios on psycho-physiological responses to urban street canyons.

This research investigated the impact of natural features on the perception of urban street canyons. The study examined the effects of three street canyons with H/W ratios of 0.5, 2, and 4 on perception. Laboratory experiments were conducted with 40 participants. The experimental stimuli consisted of audio–visual simulations. Outcomes included self-report ratings and physiological measures such as hmd and fEMG. The findings showed that H/W was positively related to perceived enclosure but negatively to pleasantness. Also, natural features, particularly trees and birdsong, enhanced the pleasantness of the streets. Overall, the results revealed that natural features significantly influenced psychological and physiological responses. The most significant changes in fEMG ZM were observed with birdsong. The research suggests optimal design configurations with H/W and the integration of natural features for perceived enclosure and pleasantness.

Study 2 [28]: Field measurement and residents' perceptions on the effects of road humps on traffic noise.

This research aims to examine the effects of road humps on traffic noise in the selected residential roads. Four residential roads in two different residential areas in Kuala Lumpur, Malaysia, were selected. A total of 543 residents took part in the study and filled out a questionnaire. In this process, housing types were recorded as terrace, apartment, flat and bungalow types. In addition to the questionnaires, LAeq, L10, L90, Lmax and Lmin metrics were recorded from 7 am to 7 pm with 15 min intervals. The findings showed that 44.3% of the respondents found traffic noise during the nighttime discomforting. Also, a similar percentage of respondents negatively perceived the daytime traffic noise. Residents' perceptions of road humps coincided with field measurements of noise. The results are presented by charts explaining the relationship between residential area and satisfaction with daytime and nighttime noise, and whether a road hump can reduce traffic noise.

Study 3 [29]: Who's afraid of pedestrianisation? Residents' perceptions and preferences on street transformation.

This research aims to understand residents' perceptions and preferences regarding the pedestrianisation of multiple streets in an area of Barcelona. The selected streets are classified based on the recent pedestrianisation, main streets, consolidated pedestrianisation and secondary streets. A total of 1211 selected district residents took part in a survey examining their views on pedestrianisation activity, noise perception, sociodemographic background and the level of traffic. According to the results, residents perceived that pedestrianisation led to an increase in public spaces and a reduction of negative traffic influences. Among the disadvantages of pedestrianisation were excessive street life and associated tumult.

Study 4 [30]: Assessment of index-based traffic noise annoyance level at major road intersections in a tourist city: A case study towards environmental sustainability.

This research investigated tourism periods, noise pollution, and their associated annoyance levels on five major roads in Bangladesh. In this process, noise measurements, surveys, and observations were applied. Noise measurements were conducted at three different times of day, during the morning, midday, and afternoon. During this period, L10, Leq, and TNI (traffic noise index) were recorded, and a survey was conducted. The survey assessed perceptions of noise pollution among 675 participants. At the end of the data collection, linear regression was used to analyse noise indices, while multinomial logistic regression was applied for TNI-related dissatisfaction. Perceived annoyance was analysed using ordinal logistic regression. Additionally, noise annoyance perceptions were examined. The results show that during tourist seasons, noise levels exceed  $Leq \leq 75$  dB on

both weekends and weekdays. Survey data show that most of the respondents perceive a rise in noise pollution during the peak tourist seasons. In these peak times, many different health effects are diagnosed in participants because of noise annoyance, such as sleep disturbance, elevated blood pressure, etc. This output proves the noise annoyance and wellbeing relations in urban tourist areas.

Study 5 [4]: Understanding Perceived Tranquillity in Urban Woonerf Streets: Case Studies in Two Dutch Cities.

This article focuses on two Dutch cities, Groningen and Leeuwarden. The study employs both laboratory and survey methods, involving 403 participants. The study has five main aims, which are to examine (1) tranquillity of the environment, (2) non-auditory factors that may influence this perception, (3) the most prevalent sounds, (4) the perception of different components of the soundscape, and (5) the variation of noise levels across different areas. Additionally, the relationship between people's actual experiences and their expectations was assessed. Perceived tranquillity was analysed across 13 Dutch cities, with a particular emphasis on Groningen and Leeuwarden. The two cities were both rated high on tranquillity levels, with minimal differences between them. Factors such as age and homeownership significantly influenced perceived tranquillity. For instance, the results revealed correlations between the 56–65 age group and the <25, 25–35, and 36–45 age groups. Motorised traffic and human activity were identified as the dominant sound sources. Furthermore, the perceived tranquillity scores were consistently higher than the predicted levels, with the strongest correlation observed between predicted and perceived tranquillity.

Study 6 [31]: Design and Effect of Guiding Sound for Pedestrians While Maintaining the Streetscape Perception.

This study explored the use of guidance sounds to assist pedestrians, particularly those with visual impairments, in navigating streetscapes without altering their perception of the environment. The researchers hypothesised that specific sound designs could guide pedestrian flow and that sound-guided interventions significantly influence the perception of streetscape. The study employed experimental environments and stereophonic sound presentation methods, using head-related transfer function (HRTF) technology to guide participants from right to left. Three distinct sound sources were used to engage participants: applause, accordion music, and nature sounds. The stereophonic presentation technology was implemented in a non-wearable format, with the sounds and human behaviour (specifically crowding factors) measured during the experiments. The study involved 16 participants, with an equal number of men and women. Questionnaires were administered in both English and German. The results indicated that guidance sounds increased comfort and motivated pedestrians to take detours. The use of stereophonic guidance sounds is generally effective, with the type of sound significantly influencing the level of motivation.

Study 7 [32]: Sensing Urban Soundscapes from Street View Imagery.

This study aimed to characterise soundscapes without relying on extensive and costly noise measurements. The researchers extracted street-level images using computer vision techniques. Based on these images, they identified and measured fifteen soundscape indicators, e.g., sound quality, sound intensity, natural sound, and human sound. Third, they developed a prediction model that combined visual features with soundscape data. The visual features were analysed in terms of various characteristics. OpenCV was used to measure pixel-level features such as brightness and saturation; Faster R-CNN was applied to identify object-level features like cars and people; DeepLabV3 focused on semantic-level features, including buildings and vegetation; and ResNet analysed scene-level features, such as downtown areas and highways. Then, researchers were employed to examine

soundscapes regarding sound intensity, quality, sources, and perceptual emotions. Overall, the study concluded that sound sources are significantly related to perceptual elements. Specifically, sound sources and visual elements were linked to emotional responses. For instance, vegetation evokes pleasant feelings and diminishes the perception of sound intensity, while traffic and machinery noises heighten impressions of chaos and annoyance.

Study 8 [33]: Role of Sounds in Perception of Enclosure in Urban Street Canyons.

For this study, 41 participants took part in the laboratory experiments. The study assessed how the soundscape influenced the perception of enclosures in urban street canyons. This research examined canyon-type streets by modelling two basic street types in a virtual environment. Particularly, the effect of geometric factors, including sound and height-to-width ratios, on perceived enclosure, spaciousness, and pleasantness, as well as the perception of sound sources, was examined. The experimental design included three conditions: visual-only, audio-only, and combined audio-visual. Visual stimuli were created through 3D modelling of narrow and wide streets with varying height-to-width (H/W) ratios, while acoustic stimuli involved modelling street sounds and transportation noise. The results specifically show that the soundscape in both the narrow and wide streets influenced spaciousness. In addition, enclosure, spaciousness, and pleasantness demonstrated strong correlations with the H/W ratios in both the visual-only and audio-visual conditions.

Study 9 [25]: The Effects of Audio-Visual Perceptual Characteristics on Environmental Health of Pedestrian Streets with Traffic Noise: A Case Study in Dalian, China.

The research examined the effect of streetscape visual and acoustic environment characteristics on environmental health. Acoustic characteristics included perceived acoustic comfort, perceived loudness, and annoyance. The visual characteristics included building height, pedestrian space width, sky visibility, spatial scale, variations in interface height and concavity, building distance along the street, building form, quantity and type of street greenery, facilities, and cleanliness. Environmental health was assessed via self-reported measures of willingness to walk, relaxation, perceptions of safety, beauty, and overall comfort. The results indicate that safety received the highest average evaluation. Rhythm and continuity were positively linked to greater willingness to walk and relaxation perception compared to other health indicators.

Study 10 [34]: Visual Perception Factors on The Soundscape of Urban Shopping Streets: Environmental Factors.

This study explored the link between soundscape perception and visual perceptions across three shopping streets in Kuala Lumpur, Malaysia, among 411 participants with a survey. These three streets are selected depending on their commercial importance, population density, sound source variety, and soundscape similarity. Particularly, the relationship between visual perception-contextual factors (e.g., appropriateness, calmness, and eventfulness) and the perception of soundscape (e.g., noise levels) of urban shopping streets was examined. The findings highlighted the significant influence of visual perception and visual quality of the environment on the acoustic environment of urban shopping streets, with users largely relying on subjective visual indicators like interest, beauty, and harmony.

Study 11 [35]: Characteristics and Perception Evaluation of the Soundscapes of Public Spaces on Both Sides of The Elevated Road: A Case Study in Suzhou, China.

This study aims to explore the perception of soundscape characteristics along elevated roads. The methodology involved both field studies and a survey with 1159 participants. A single street in Suzhou, China, was selected and divided into 20 distinct sections. Participants evaluated these sections based on semantic indicators, sound source perception, and overall soundscape assessment, e.g., quietness, pleasantness, eventfulness, and distinctive-

ness. Objective measurements of sound levels were conducted to analyse the relationship between perceived soundscapes and actual sound levels. Results revealed significant differences in actual sound levels across pedestrian areas, street parks, and commercial plazas. Vehicle noise was identified as the most dominant sound source, followed by human activities and natural sounds. The presence of natural sounds increased satisfaction, while controlling horns and sirens played a key role in mitigating negative perceptions of soundscapes.

Study 12 [36]: The Influences of Vegetation and Water Features on The Perception of Urban Streets.

This particular study focused on the relationship between water and vegetative elements and their influence on urban streets. Specifically, the study examined the influence of natural sounds, such as water sounds and birdsong, on the perception of enclosure in urban street canyons with varying height-to-width ratios.

In a 1-by-3 laboratory experiment, 10 participants watched videos of urban street canyons with audio-only, visual-only, or audio-visual conditions via VR. People rated each stimulus at 11 different points in virtual environments regarding characteristics such as spaciousness, etc. In the audio-visual condition, participants gave ratings on enclosure, spaciousness, pleasantness, and source width perceptions. In the audio-only condition, only perceived pleasantness and perceived source width were evaluated. The visual-only condition included questions on enclosure, spaciousness, and pleasantness.

This research serves as a preliminary study. The results indicate that participants in the visual-only condition rated enclosure significantly higher, showing a notable relationship between perception and the H/W ratio.

Study 13 [23]: Research on the Healing Potential of Rural Community Streets from The Perspective of Audiovisual Integration: A Case Study of Four Rural Communities in China.

The research focuses on the healing effects of visual environments among rural communities in southwestern China across 57 participants. Thirteen different street types were selected across four regions, including artificial enclosure streets, natural enclosure streets, mixed artificial-natural enclosure streets, artificial-natural semi-enclosure streets, natural semi-enclosure streets, natural-artificial semi-enclosure streets, artificial open streets, and natural open streets. Participants were exposed to 30 s soundscapes combining birdsong and traffic noise. The physiological responses, such as pulse and systolic blood pressure, and self-report responses of being away, extent of beauty, fascination, and compatibility were measured to assess the healing effects. The results indicated that birdsong had a positive impact on participants' healing indicators. Furthermore, the findings demonstrate a positive correlation between subjective perceptions of healing and aesthetic preferences.

Study 14 [37]: How Do Shared-Street Design and Traffic Restriction Improve Urban Soundscape and Human Experience? An Online Survey with Virtual Reality.

This study focused on the effect of traffic restrictions and street design on soundscape perceptions among 106 participants from Italy. The study developed four distinct scenarios where Piazza Vittoria in Italy was used as the background environment, incorporating both visual and auditory elements. These scenarios differed based on changes in street design (shared versus non-shared) and the presence of traffic restrictions. Virtual reality (VR) was used to present scenarios to participants. Participants then rated each scenario regarding various visual elements, including vegetation, traffic, fountains, buildings, pavement, and sea views. Sound environment comfort (e.g., traffic noise, bird sounds, water, and human activity) and the presence of facilities and human activities (e.g., benches, shops, shaded areas, and people) were also measured. Respondents evaluated the scenarios using descriptors like calm, pleasant, exciting, eventful, chaotic, monotonous, unpleasant, and

uneventful. The results suggest that traffic restrictions improve soundscape perceptions, where restricted areas are perceived as calmer and less chaotic compared to areas with no restrictions. Shared street designs were also shown to contribute to a calmer atmosphere.

Study 15 [38]: Effect of Odour on Multisensory Environmental Evaluations of Road Traffic.

This research investigated how odour evaluations affect perceptions of noise, landscape quality, and the overall environment. Twenty participants took part in an experiment where they were presented with audio–visual odour stimuli, which consisted of 10 min of sound recordings presented with 14 different environments which varied in traffic volume, tree screening, and presence of odours. Following the stimulus presentation, participants assessed the environment regarding loudness, noise annoyance, landscape quality, and overall scene pleasantness. Additionally, they provided feedback on odour-related factors such as odour quality, intensity, and appropriateness. The results indicated that odour pleasantness did not have an effect on noise annoyance, perceived loudness, landscape quality, or overall pleasantness.

Study 16 [39]: Seasonal preferences and interactions of visual/auditory elements of streetscape in Namwon City, Korea.

This research examined how seasonal changes affect people’s experiences of urban environments in Namwon City, Korea. The study used both surveys and participant observation to examine visual elements such as greenery, architectural styles, and street layouts, as well as sound elements such as street noise, natural sounds, and community activities. The findings revealed that seasonal changes significantly impact people’s perceptions and preferences regarding the urban environment. Mainly, individuals tend to favour blooming flowers and green landscapes, which are highest in spring and summer. The findings suggest that urban land use planning can enhance natural and ecological soundscapes. Consequently, urban planning should account for these seasonal variations by creating adaptable and appealing urban spaces.

### 3.3. Data Extraction

Articles were included based on three parameters: soundscape measures, streetscape characteristics and study design.

The soundscape characteristics encompass various perceptual and acoustic indicators, including noise annoyance, pleasantness, perceived affective quality, restorativeness, soundscape quality, and appropriateness (see Table 1) [40]. These measures provide a comprehensive understanding of how individuals perceive and evaluate sound environments.

**Table 1.** Summary of studies and focus areas.

Article Name	Focus of Study
Yilmaz et al., 2025 [27]	Aims to explore how natural features affect the perception of street canyons.
Ahmed Sofi and Kadar Hamsa 2025 [28]	The study analyses the effect of road humps on actual and perceived traffic noise among residents.
Nello-Deakin et al., 2024 [29]	Aims to understand the relationship between street pedestrianisation and perceived traffic calm among pedestrians.
Nath et al., 2024 [30]	Evaluates the noise perceptions of residents and workers and associated annoyance.
Leereveld et al., 2024 [4]	Assesses the relationship between the presence of outdoor vegetation and the level of noise annoyance.
Kuratomo et al., 2023 [31]	Investigates how pedestrians can benefit from guiding sounds.

Table 1. Cont.

Article Name	Focus of Study
Zhao et al., 2023 [32]	Aims to characterise soundscapes and visual elements.
Yilmaz et al., 2023 [33]	Examines the influence of sound on the perception of enclosures in urban street canyons with varying height-to-width ratios.
Ren et al., 2023 [25]	Examines the effect of audio–visual characteristics on environmental health.
Abdul Hamid et al., 2023 [34]	Assesses visual perception factors in the soundscape of urban shopping streets.
Li et al., 2022 [35]	Explores soundscape characteristics in public spaces and identifies factors influencing soundscape evaluations.
Yilmaz et al., 2022 [36]	Examines the influence of natural sounds, such as water and birdsong, on the perception of enclosure in urban street canyons.
Fu et al., 2022 [23]	Investigates the healing potential of different types of rural community streets based on visual characteristics.
Jiang et al., 2018 [37]	Aims to understand how shared street design and traffic restrictions contribute to the soundscape and explores how street management scenarios relate to human experiences.
Jiang et al., 2016 [38]	Examines how odours impact perceptions of noise, landscape, and the overall environment
Han et al., 2011 [39]	Examines the effect of seasonal variations on audio–visual perceptions of residents.

The selected articles focus on outdoor street environments, such as commercial streets, pedestrianised streets, and other distinct street typologies. Streetscape features are not limited to soundscape characteristics but also include sensory experiences and spatial perceptions, offering a broader perspective on environmental quality.

The study design section summarises the methodological approaches employed in the articles, including laboratory studies and questionnaires. This categorisation highlights the methods and contexts of the studies, providing a structured overview of the research frameworks used (see Table 2).

Table 2. Investigated soundscape measurements and streetscape features.

	Soundscape Indicators	Streetscape Features	Methodological Scale			
			Study Design	Sample Size	Physiological Response	
1.	Yilmaz et al., 2025 [27]	Enclosure and pleasantness	Natural features	Laboratory, questionnaire	40	HMD, fEMG
2.	Ahmed Sofi and Kadar Hamsa 2025 [28]	Noise perception	Temporary changes (daytime changes), road hump	Questionnaire	543	
3.	Nello-Deakin et al., 2024 [29]	Noise perception	Architectural features (type of street), vehicle features (transportation type, transportation usage), human behaviour and presence.	Survey	1211	
4.	Nath et al., 2024 [30]	Perception of noise pollution	Temporary changes (seasonal changes)	Questionnaire	675	
5.	Leereveld et al. (2024) [4]	Pleasantness, eventfulness, tranquillity	Natural elements (sky, greenery)	Laboratory, questionnaire	403	
6.	Kuratomo et al. (2023) [31]	Sound comfort	Human behaviour and existence (flow of crowd)	Laboratory, questionnaire	16	
7.	Zhao et al. (2023) [32]	Annoyance, monotony, sound intensity, sound quality	Natural elements (parks, sky, vegetation), architectural features (buildings, highways, downtown), traffic features (car, truck, bus, motorcycle), human presence	Laboratory, field study	300	
8.	Yilmaz et al. (2023) [33]	Pleasantness, spaciousness, enclosure	Architectural features (urban canyon height to width)	Laboratory, questionnaire	41	HMD
9.	Ren et al. (2023) [25]	Sound comfort, loudness, preference, and annoyance	Architectural features (building height, width of pedestrian space, spatial scale, building width, building form), natural elements (sky visibility, quantity of green areas, type of greenery)	Questionnaire, laboratory	39	

Table 2. Cont.

	Soundscape Indicators	Streetscape Features	Methodological Scale			
			Study Design	Sample Size	Physiological Response	
10.	Abdul Hamid et al. (2023) [34]	Appropriateness, eventfulness, calmness	Visual perception (interesting, beautiful, and harmonious), visual quality	Survey	411	
11.	Li et al. (2022) [35]	Perceptual assessment	Architectural features (elevated road), temporary changes, natural elements	Field study, questionnaire	1159	
12.	Yilmaz et al. (2022) [36]	Enclosure	Natural elements	Laboratory	10	HMD
13.	Fu et al. (2022) [23]	Healing perception, subjective loudness	Natural elements, visual aesthetic	Laboratory, questionnaire	57	Pulse, systolic blood pressure
14.	Jiang et al. (2018) [37]	Pleasantness, exciting, chaotic, calmness, monotonous, eventfulness	Traffic features, natural elements, architectural features (street scale)	Laboratory, survey	106	
15.	Jiang et al. (2016) [38]	Noise annoyance, pleasantness	Traffic, environmental quality, natural elements	Laboratory, questionnaire	20	
16.	Han et al. (2011) [39]	Preference	Temporary (seasonal) changes, architectural features, natural elements	Survey	45	

#### 4. Discussion

This research presented an overview of the current literature on the perception of soundscape and streetscape features. This section discusses the findings in relation to the research questions, and highlights common trends, significant gaps, and insights derived from the literature. RQs focused on the type of soundscape features, streetscape features, and key methods used in the recent literature. We were also interested in under-represented soundscape and streetscape features in the reviewed research.

There has been a notable increase in the number of studies focusing on soundscape after 2000; hence, the present review covers research published between 2000 and 2025. The majority of these were published within the last two years, which is a clear indication of soundscapes emerging as a new research trend (see Figure 2). The sixteen studies included in this review were conducted by researchers from Asian and European countries, and from the UK with several international collaborations. However, there were no samples from the USA, Africa, and the Middle East, indicating a need for greater diversity in this field.

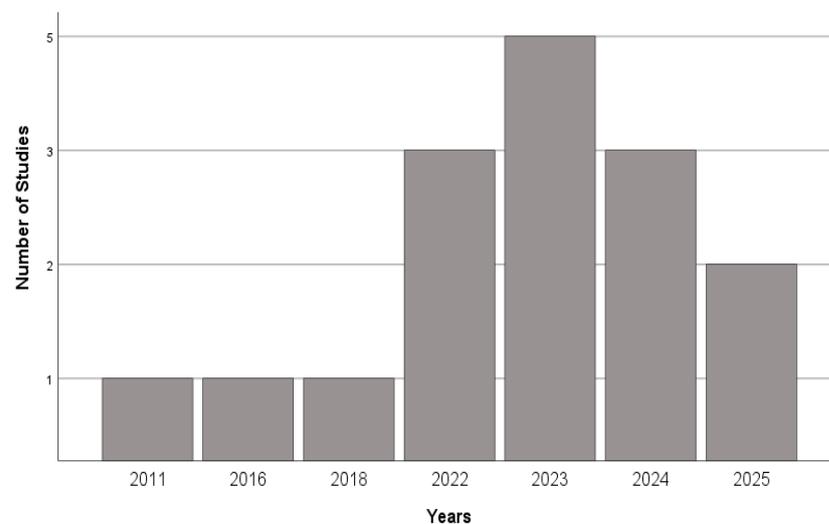
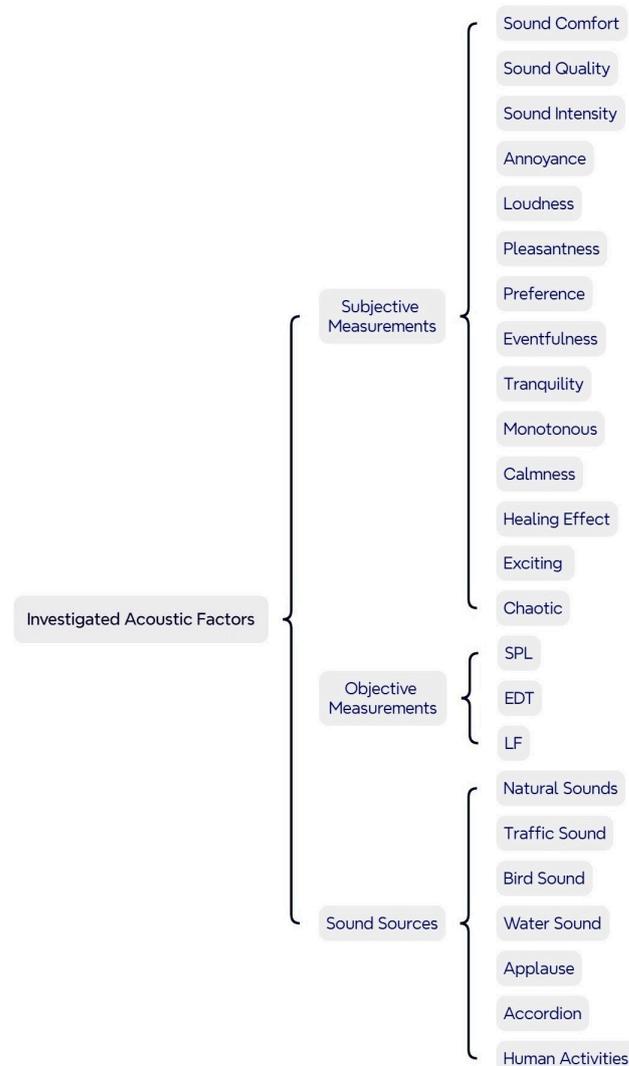


Figure 2. Distribution of selected studies by year.

#### 4.1. First Research Question: What Type of Soundscape Features Have Been Investigated in the Street Soundscape Context, and Which Are Under-Represented?

The selected publications predominantly explored the concepts of sound comfort, noise annoyance, pleasantness, and preference for a street atmosphere among participants (see Figure 3). Acoustic comfort was investigated in three studies, and this idea is extended by acoustic parameters [25,28,31,37]. This concept has also been examined within the broader framework of urban health, particularly concerning safety, relaxation, and mental wellbeing [25,41]. Findings indicate that acoustic comfort, influenced by natural sound sources, can significantly motivate pedestrians [31]. Conversely, traffic noise was shown to reduce sound comfort, underscoring the importance of implementing traffic restrictions and shared street designs to create calmer, more comfortable, and pleasant sound environments [37]. Pleasantness is another key characteristic of soundscapes examined in the literature, which was evaluated in terms of pleasure and relations with different sound subjects [37,42]. In addition, sound intensity, appropriateness, spaciousness, tranquillity, eventfulness, and enclosures have been researched in the literature.



**Figure 3.** Investigated and implemented acoustics measurements in selected articles (SPL, sound pressure level; EDT, early decay time; LF, lateral energy fraction).

In street soundscape contexts, research has predominantly focused on natural sound sources, including birdsong, water sounds, and vegetation sounds. These features are consistently linked to a higher level of positive perceptions, such as tranquillity, relaxation,

and acoustic comfort [25,27,31,36,39]. Birdsong has been shown to reduce noise annoyance, particularly in rural or park-like urban settings, while water sounds contribute to perceptions of calmness and aesthetic appeal (Fu et al., 2022; Yilmaz et al., 2022) [23,36]. Also, seasons influence sound preferences; in warmer seasons, people tend to appreciate natural sounds like birdsong or rustling leaves, while in colder seasons, social sounds like conversations and communal activities become more prominent [23,39].

Conversely, traffic noise and elevated sound levels are commonly identified as sources of annoyance and contributors to unhealthy environments [25,35]. Among traffic-related sounds, horns and sirens are considered the most dominant and irritating, surpassing other environmental sounds, such as mechanical noises [35]. Traffic-based studies also highlight the interaction between the presence of odours, seasonal changes in tourism, and the effects of pedestrianisation [38]. L. Jiang et al. (2016) [38] found that odours have the potential to modulate noise perception. Their research measured people's perceptions of noise annoyance in the presence of rose scents and varying traffic levels. The results indicate that the presence of odours influences people's perception. On the other hand, studies show that traffic noise and annoyance levels increase significantly during peak tourist seasons [30]. The reduction in traffic due to pedestrianisation has enhanced positive impacts for both residents of pedestrianised streets and those living on adjacent streets [29].

Overall, the findings of this review align with the prominent themes examined in current soundscape research, particularly regarding sound comfort, noise annoyance, and pleasantness. However, the literature also explores various other aspects of sound, such as music-likeness, perceived affective quality, and appropriateness. These aspects have not yet been incorporated into street soundscape research [40]. Within the context of street soundscapes, there is a clear need for further research that specifically addresses the impact of different soundscape features in several types of streets such as high streets, rural streets, commercial streets, etc.

#### *4.2. Second Research Question: What Kind of Streetscape Features Are Most Frequently Examined in the Street Soundscape Literature? (RQ2)*

Streetscape features have been extensively studied in the literature with a focus on natural elements, human factors, traffic elements, architectural features, and visual features. In general, research primarily utilises natural elements, which are mentioned in 9 out of 16 studies. These include greenery (e.g., tree canopies, flowers, vegetation) and water features (e.g., waterfalls, fountains), which are consistently linked to perceptions of tranquillity, restorativeness, ecological benefits, and aesthetic value [4,23,25,32,35–39]. The findings from Han et al. (2011) [39] and Li et al. (2022) [35] indicate that seasonal changes significantly influence human perceptions, particularly in terms of preferences for visual environments. For instance, the study by Han et al. (2011) [39] highlights the effect of natural visual elements (e.g., blossoms, greenery) on audio–visual preferences across different seasons. The studies by Yilmaz et al. (2022) [36], Li et al. (2022) [35], and Leereveld et al. (2024) [4] focused solely on the relationship between natural elements (sky visibility, greenery) and soundscapes. In contrast, Fu et al. (2022) [23] investigated natural elements regarding visual perception factors, such as openness, enclosure, and aesthetics. Similarly, Zhao et al. (2023) [32], Han et al. (2011) [39], Ren et al. (2023) [25], and Jiang et al. (2018) [37] examined both architectural features and natural features together. These findings highlight the importance of integrating natural and built elements to create pleasant and restorative urban environments.

Another common streetscape feature is traffic elements (e.g., cars, trucks, buses, motorcycles), which were examined in six studies. These studies focused on aspects such as traffic density, traffic restrictions, and road types [32,37,38]. The results indicated that traffic restrictions had a positive effect on the street perception [29,37], while road humps

were perceived as reducing noise levels [28]. Additionally, noise levels and noise perception during nighttime and morning hours were found to significantly influence residents' satisfaction [28]. These outputs show that traffic policies and traffic planning influence the pedestrians' perceptions.

The term 'density' refers not only to traffic but also to human presence or crowds. Three studies focused on human presence and behaviour [31,32]. The presence of people and crowds plays an important role in designing environments that are more accessible, comfortable, interactive, and pleasant. Kuratomo et al. (2023) [31] found that only natural sounds influenced the perception of pedestrian walking paths, while human applause or music had no significant effect. Zhao et al. (2023) [32] incorporated human semantics (the percentage of pixels classified as a person or rider) as one of the visual feature variables.

Similarly, street scale and proportion were only examined by two studies [25,33]. For instance, Yilmaz et al. (2023) [33] investigated the effects of canyon-type street scale differences on perceptions of enclosure, spaciousness, and pleasantness. These studies also examined factors such as building forms, facades, distances, scales, structures, and objects. The results showed that perceived spaciousness is influenced by the sound environment and has a weak correlation with pleasantness. Furthermore, the height-to-width ratio of streets affects perceptions of enclosures, spaciousness, and pleasantness [33].

The temporary variations, such as seasonal, daily or event-based changes, were also examined in the streetscape literature. For instance, Nath et al. (2024) [30] showed that during the tourist season, noise pollution significantly increased at three different times of the day (morning, midday, and night), which then negatively impacted public health [30]. Han et al. (2011) [39] indicate that people's perceptions are more positive in spring, summer, and autumn, whereas in winter, they prefer human-centred visuals such as festive decorations or social interactions [39].

Additionally, overall visual perception and the visual quality of the environment were important factors in shaping soundscape perceptions [34]. Abdul Hamid's research particularly highlights the significance of beauty and harmony. The only multisensory study by Jiang et al. (2016) [38] indicated that the pleasantness of odours did not affect noise annoyance, perceived loudness, landscape quality, or overall pleasantness. In summary, while natural and traffic-related features are the most frequently examined aspects of streetscapes, other streetscape aspects such as human presence, street scale, temporary variations (seasonal–daily changes), and speed perception are less examined. These refer to how pedestrians and drivers perceive the speed of vehicles.

#### *4.3. Third Research Question: Which Methodological Approaches Have Been Implemented in Street Soundscape Studies?*

According to the BSI (British Standards Institution) (2018), soundscape research identifies and applies various methodologies in scientific studies, such as soundwalks, etc. This review reveals two types of measurements in previous research: field observations and participant-based measures. Participant-based qualitative and quantitative methods, including surveys and interviews, involve between 10 and 1200 participants [4,23,28–30,34,42]. Field-based data are collected using mapping, sound measurements, experimental environments, and 3D modelling; see Table 2 [33,37,38]. Field-based data are used to create experimental stimuli as well as to collect objective measurements.

Another key methodology, i.e., assessment of physiological responses to streetscape stimuli, was examined in four out of sixteen studies. Physiological measurements are valuable tools for tracking human emotional reactions to specific conditions [43]. Mainly head-mounted displays (HMDs), blood pressure, and pulse factors were used to measure physiological responses [23,33,36] (see Table 2). However, research on behavioural and physiological outcomes remains limited and fails to present consistent evidence [32,43,44].

Also, this method has several drawbacks, such as the cost of specialised equipment and the need for expertise in this field. Additionally, data collection can be time-consuming; hence, studies may end up with small sample sizes [23,27,33,36]. Furthermore, participants' personal health issues should be taken into account to eliminate error or confounding results. For example, using heart rate to measure responses to street-level sounds could be compromised if a participant has an undiagnosed heart condition, which may skew the data. As a result, future research should consider physiological measurements to create more reliable and correlated health outcomes with consideration of potential limitations.

This review encompasses both journal articles ( $n = 13$ ) and conference papers ( $n = 3$ ). Participant numbers had a broad range. In general, the majority of studies in the literature have fewer than 100 participants. Studies with the highest sample sizes typically employed random selection and minimal inclusion criteria. The current review's inclusion criteria solely focused on the absence of hearing or visual impairment. Some studies also considered participants' professional backgrounds, occupations, or local residences (e.g., a specific neighbourhood or street), as indicated in Table 2 [23,32]. Nello-Deakin et al. (2024) [29] focused on residents' perceptions of different street types, including main streets, secondary streets, consolidated pedestrianised areas, and newly pedestrianised areas. Perceptions of streets, whether positive or negative, vary depending on whether residents live on pedestrianised or other types of streets [29]. These selection criteria suggest that the findings may not be generalisable for the general population. Moreover, the respondents' characteristics, such as age, education level, occupational status, and frequency of visits, influence the perception, but gender does not [35]. Hence, future research needs to recruit more representative samples for a more comprehensive understanding of soundscape and streetscape perceptions.

#### 4.4. Research Agenda

This review shows that the existing literature on street soundscapes offers a limited understanding of the phenomenon. Particularly, research on the range of sound sources and perceptual dimensions is lacking. Human-generated sounds in street environments, such as those from events, religious ceremonies, and commercial activities, remain largely unexplored, even though they are integral to the urban street experience. Similarly, transportation sounds, including scooters, bicycles, and trains, have not been sufficiently examined. The past research shows traffic elements impact people's perception in a wide range of domains [37]. Another significant gap is the limited focus on how street noises affect perceptions of various characteristics, such as soundscape quality, vibrancy, and quietness [40].

The existing streetscape features fell into four categories: physical street elements, street context typology, dynamic atmosphere, and temporary changes. The current literature does not seem to provide a comprehensive understanding of these features. For instance, street furniture, road materials, building facades, and lighting materials are examples of essential physical streetscape features [45]. These can be further expanded to include the texture and colour of various elements. Future research should also focus on street typology. For instance, pedestrian streets, high streets, and different types of rural streets have different architectural and soundscape characteristics, which require further investigation [46]. Also, temporary variations such as daily, seasonal, or event-based changes can also impact soundscape/streetscape perception, although they have not been thoroughly examined by enough research. Lastly, streets do not only contain stable elements but also include dynamic ones such as human or vehicle movements [45]. The perceptual effect of speed is another important factor to examine in street soundscape research. Vehicle speed

may influence pedestrian stress levels and sound perceptions, highlighting a potential area for further investigation.

Future research could greatly benefit from adopting novel methodological perspectives. For instance, integrating soundwalks, multisensory measurements, and diverse stimulation techniques could offer valuable tools for data collection and analysis [40,42]. Moreover, future studies should include a more diverse and representative sample, considering factors such as age, gender, and nationality. Special attention should be given to under-represented groups, including the elderly, people with disabilities, and children, as their perspectives are essential for comprehensive findings [45]. For example, differences in soundscape and visual perception between these groups could provide valuable insights for various under-represented populations. Moreover, research focusing on nationality-based variations could highlight how cultural differences influence human perceptions of sound and space, shaping street design. Such studies would contribute to localised design strategies and promote community wellbeing. In addition, the literature introduces the concept of a healthy street perspective. This perspective evaluates the health of streets using ten different metrics, including noise, air quality, safety, and accessibility [47]. Despite the lack of related research on this topic, incorporating a soundscape perspective could significantly enrich the framework.

Lastly, behavioural and physiological approaches are notably absent in the current soundscape literature [40,43]. Physiological measurements play an important role in tracking human emotional and behavioural changes during experiments and providing evidence of their feelings [43]. Future methodological frameworks could benefit from incorporating various physiological measurements such as heart rate (HR), high frequency (HF), heart rate variability (HRV), functional MRI (fMRI), positron emission tomography (PET), skin conductance level (SCL), respiration rate (RR), and electromyography (EMG). These measurements could help assess affective responses, such as reactions to fear-inducing stimuli, and analyse brain activity in response to sensory inputs. Adopting this perspective would enhance our understanding of the relationship between health indicators and environmental perception.

#### 4.5. Limitations

While the findings of this study offer valuable insights, there are also several limitations. The review was restricted to research available in Scopus and ScienceDirect, potentially limiting the diversity of studies considered. This research includes only 16 articles, which poses a limitation for understanding trends and generalising findings across the entire literature. The main reason for this is the criteria used to select studies, i.e., the focus on soundscapes and/or streetscapes in the context of outdoor spaces. Considering soundscapes as a newly emerging research field where the majority of studies were conducted in recent years, the limited number of studies seems plausible. Another limitation is that this study involved two reviewers, where the first completed the initial selection of the studies and the second conducted the subsequent check. This process may have introduced potential biases into the results. Also, the review included sources only in English, which could have limited the scope of the review.

## 5. Conclusions

This review aims to identify investigated soundscape features in street soundscape contexts. The current review identified sixteen studies in the recent soundscape literature, as detailed in Table 1. The key findings and recommendations of this research can be summarised as follows:

- The most-studied aspects of sound perception were sound comfort, sound preference, pleasantness, and noise annoyance. Natural and traffic sounds are the main sources studied. In general, natural sound sources are related to positive perceptions, whereas traffic sounds are related to negative perceptions. Human-generated sounds and transportation sounds, like scooters, bicycles, and trains, have not been adequately studied. There is also a notable gap in understanding how street sounds influence different perceptions such as safety, eventfulness, and calmness.
- From the streetscape feature approach, the soundscape literature predominantly focuses on natural elements, such as vegetation and water features, and traffic-related elements. In general, natural elements are related to tranquillity and positive perceptions. In this scope, tree canopies, flowers, and vegetation elements are investigated. Traffic-related elements are generally investigated to determine the annoyance from traffic. Temporary changes in streets are investigated with tourist season changes and daily changes on streets. The results show that temporary changes influence people's perception. Therefore, future research should investigate various other streetscape features, including physical street elements (lighting elements, urban furniture, etc.), speed perception, and temporary changes.
- The selected research methodologies predominantly employ questionnaires and laboratory-based methodologies within healthy adult groups. Overall, the number of study participants ranges between 10 and 1200 individuals. Only a limited number of physiological measurements are applied, such as HMD and fEMG. These findings emphasise the need for the implementation of more diverse physiological methods in future research. More representative samples need to be used to increase the generalisability of the results.

This study presents key findings and critical recommendations for improving street soundscapes, focusing on their relationships with various street typologies, components, pedestrian groups, and the principles of healthy soundscape design. These findings and recommendations offer valuable insights for researchers and professionals working to create more comprehensive and liveable street soundscape environments. In the future, greater collaboration across research disciplines, including architecture, landscape design, sociology, psychology, and urban management (encompassing local governance and municipal management), should be encouraged to develop models for both urban and rural street soundscape environments. Such collaborations would facilitate the identification of soundscape conditions in street contexts.

**Author Contributions:** Conceptualization, Z.S.O., F.A. and J.K.; methodology, Z.S.O., J.K. and F.A.; validation, Z.S.O., J.K. and F.A.; formal analysis, Z.S.O.; investigation, Z.S.O., J.K. and F.A.; resources, Z.S.O.; data curation, Z.S.O. and F.A.; writing—original draft preparation, Z.S.O.; writing—review and editing, Z.S.O., J.K. and F.A.; supervision, J.K. and F.A.; project administration, J.K. and F.A.; funding acquisition, Z.S.O. All authors have read and agreed to the published version of the manuscript.

**Funding:** The First Author's Phd was funded by the Turkish Ministry of National Education, Republic of Turkiye.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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