Environmental Factors and Healthcare Innovations Among Professionals of Selected Healthcare Facilities in Ibadan Metropolis

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Abstract

This study investigated the impact of environmental noise on the welfare and overall well-being of individuals with frailty or dementia in tropical regions, specifically focusing on direct and indirect adverse effects on cognitive decline, the exacerbation of dementia symptoms, and the challenges it poses to caregiving. The research involved 135 participants from two healthcare facilities in Ibadan City, Nigeria (HC1 and HC2), comprising families, caregivers, social workers, registered nurses, and highly trained professionals who assist individuals with dementia and frailty.

Given the nature of the investigation, primary data were collected through non-intrusive environmental monitoring instruments, clinical data from healthcare facilities, and descriptive observation-based questionnaires. These data were subjective and focused on observational insights. The study concentrated on private and government care facilities in Ibadan, Nigeria, highlighting substantial potential for improvement in care practices and environmental management within these settings. The findings of this research indicate that noise exposure is a significant concern for individuals with frailty or dementia, particularly in terms of their care and overall well-being. The study found that environmental noise contributes to cognitive impairment, exacerbates dementia symptoms, and presents considerable obstacles to effective caregiving in tropical regions. These results underscore the need for targeted interventions to mitigate the impact of noise on this vulnerable population. The study concludes with recommendations for the implementation of noise reduction strategies in care facilities, emphasizing the importance of creating a more conducive environment for individuals with frailty or dementia.

Keywords: *Dementia care, Environments, Frailty, Healthcare facilities, Interventions, Noise*

Introduction

The study of the interplay between environmental factors and health outcomes, particularly noise pollution, is a crucial area of research, especially in tropical regions where urbanization and population density are high. Noise pollution, defined as unwanted or harmful sound, is prevalent in many urban and suburban areas worldwide and has been recognized by the World Health Organization (WHO) as a significant public health issue. It is associated with various adverse health outcomes, including cardiovascular disease, sleep disturbances, and cognitive impairment.

The relationship between noise pollution and health outcomes is particularly complex for individuals with frailty and dementia (Kostis et al., 2018). Environmental noise can exacerbate symptoms of frailty by inducing stress and disrupting sleep, which further deteriorates physical health. For those with dementia, noise pollution can lead to increased confusion, agitation, and cognitive decline, making it more challenging to manage their condition effectively (Chen-Edinboro et al., 2015). This issue is especially pressing in tropical regions, where higher population densities, rapid urbanization, and weaker environmental regulations intensify the problem.

Frailty and dementia predominantly affect the elderly and are significant health concerns in tropical regions. Frailty is characterized by reduced strength and physiological function, increasing vulnerability to adverse health outcomes (Mudu & Costa, 2018). Dementia, including conditions like Alzheimer's disease, severely impairs memory, thinking, and social abilities, interfering with daily life. The architectural designs in tropical regions often fail to insulate against external noise, and cultural practices may contribute to higher ambient noise levels. Additionally, limited resources in these regions can hinder efforts to mitigate noise pollution and provide adequate care for vulnerable populations.

Historically, the impact of noise on patient health has been recognized, with Florence Nightingale noting that unnecessary noise can harm patients. Modern research supports this view, indicating that noise exposure is particularly concerning for aging populations, as it can lead to cognitive impairment and contribute to dementia development. In healthcare settings, noise can affect patients' sleep, cardiovascular responses, length of hospital stays, and re-hospitalization rates (Kjellstrom & Mercado, 2017). In tropical climates, where open windows and outdoor activities are common, individuals with frailty and dementia are at increased risk of exposure to environmental noise. Poor indoor environments in healthcare facilities, characterized by excessive noise, can severely impact the lives of these individuals, exacerbating their behavioral and psychological difficulties. For those with dementia, high noise levels can increase anxiety, complicate communication, and cause overall distress, as their ability to filter out background noise diminishes (Laumon et al., 2020).

This study therefore examines environmental factors and healthcare innovations among professionals of selected healthcare facilities in Nigeria. It will focus on how noise pollution in healthcare environments in Ibadan, Nigeria, a tropical region, affects individuals with frailty or dementia, particularly in terms of their care and overall well-being. It examines the direct and indirect consequences of noise on cognitive decline, the worsening of dementia symptoms, and the challenges it poses for caregiving. This research aims to explore the specific impacts of environmental noise on these vulnerable populations in tropical regions, highlighting the implications for care practices and the need for better noise management in healthcare settings.

LITERATURE REVIEW

The exploration of how environmental noise affects individuals with frailty or dementia, particularly in tropical regions, is an increasingly important area of study due to its implications for health and well-being. The relationship between noise and cognitive function, the exacerbation of dementia symptoms, and the challenges it poses to caregiving have significant ramifications. This literature review synthesizes existing research through three primary frameworks: conceptual, empirical, and theoretical. Each framework will explore various aspects of noise impacts, design features, and the importance of acoustics in environments tailored for individuals with frailty or dementia.

Conceptual Framework

The concept of acoustics, which encompasses the science of sound generation, control, transmission, reception, and impact, is fundamental in understanding its influence on care environments for frail and dementia-affected individuals. In settings where clear communication is essential, it is crucial to mitigate unwanted noise to alleviate distress and anxiety (Department of Health, 2013). The acoustic design of care environments for individuals with dementia or frailty must address several key factors, including the frequencies that are most commonly impaired with aging, the confusion and sensory overload caused by excessive noise, and the potential positive impact of certain sounds on this vulnerable population (Bharathan, 2007).

Acoustic seclusion is a critical design element in creating environments that cater to frail and dementia-affected individuals. This can be achieved through the use of sound-absorbing materials and careful spatial design. Effective acoustic design involves creating distinct areas and rooms that are separated by sound-absorbing partitions and employing building materials that reduce noise transmission. Evaluating the direction and origin of noise—whether it travels horizontally or vertically—helps in designing environments that minimize disruptive sounds. Surfaces, fixtures, and fittings made from sound-absorbing materials contribute significantly to creating tranquil and restful settings (Brawley, 2001). In addition, incorporating noise-reducing design solutions and sound-effect technology into the built environment is essential for promoting well-being (Anderzhon et al., 2007).

In practice, noise control features such as soundproof walls and acoustic tiles play a crucial role in minimizing noise within multifunctional rooms. Acoustic flooring, which includes laminated layers of insulation within linoleum, helps reduce both horizontal and vertical noise. Sound-absorbing vinyl flooring and carpets also contribute to minimizing noise propagation (Anderzhon et al., 2007). Internal partitions, screens, and drapes can be used to limit noise and achieve suitable sound levels in environments designed for individuals with frailty or dementia. Automatic door closures can help alleviate the stress caused by sudden loud noises, while furniture that absorbs sound and the avoidance of excessive clutter contribute to a less disruptive environment (Bharathan, 2007).

Quiet rooms are a critical feature in acute, social, and community care settings, providing spaces where patients with frailty and dementia can experience a more serene environment. These rooms can be used for therapeutic purposes such as recollection therapy and personal interactions. Their inclusion in the design of acute wards, residential care homes, and community day centers is essential for facilitating positive interactions between patients, family members, caregivers, and visitors. When space is limited, technological solutions can be employed to enhance these quiet spaces (Brawley, 2001).

High-quality indoor sound systems that produce soothing effects, such as natural or familiar sounds, are also vital. These systems can help relieve discomfort and anxiety, particularly in areas where individuals with frailty and dementia might feel apprehensive. Adapting sound systems to consider cultural variations and individual preferences enhances their effectiveness. For example, sound-effect devices that mimic natural sounds, such as bird songs in gardens, can provide comfort and aid in orientation (Alessi et al., 1999).

Incorporating large push buttons that play soothing sounds, such as beach waves or rural bird cries, can help connect individuals to nature and support their orientation in both indoor and outdoor spaces. These features can be integrated into furniture and bespoke fixtures to cater to individual needs and preferences, while also being designed to avoid confusion in frail and dementia-affected individuals (Bharathan, 2007). The integration of natural soundscapes and thoughtful acoustic design is integral to creating environments that support well-being.

Noise control and room layout are pivotal in achieving acoustics that suit the needs of individuals with frailty and dementia. Distinct solutions are required for private and public spaces, with careful consideration given to the arrangement of circulation, social, eating, and activity spaces. Low ceilings are recommended to minimize noise, and mechanical, electrical, and plumbing systems should be positioned away from areas where people with dementia spend significant time. The strategic arrangement of furniture can enhance the acoustic qualities of care environments (Brawley, 2001).

Empirical Framework

Research has consistently shown that noise exposure in healthcare settings impacts both staff and patients, influencing job performance and overall satisfaction. Noise has been linked to increased stress and alterations in job performance, with significant correlations between noise levels, stress, and occupational satisfaction. Environmental health experts identify noise exposure as a factor contributing to negative stress, dissatisfaction, and psychological impacts among healthcare workers (Gagnon et al., 2012; Schwartz, 2008).

The "overload hypothesis" provides a theoretical basis for understanding how excessive noise disrupts cognitive processes. This hypothesis suggests that humans have a limited capacity for processing stimuli and cope with sensory overload through selective attention, often ignoring less critical inputs (Sundstrom et al., 1996; Waye et al., 2010). Noise-induced cognitive fatigue can impair concentration and mental performance, leading to reduced work quality and increased stress levels. Alarm fatigue is another significant concern associated with noise in healthcare environments. High frequencies of alarms can desensitize staff, leading to delayed or missed responses and decreased recognition of critical alarms. Issues such as background noise masking alarms and staff hearing acuity contribute to alarm fatigue, which has detrimental effects on patient safety (Graham et al., 2010). The impact of noise on oral communication is also critical, as poor acoustics and background noise can hinder effective communication, leading to medical errors such as incorrect medication administration (Marcionite et al., 2015).

The negative impact of noise on patients is particularly pronounced in healthcare settings. Sleep deprivation caused by excessive noise is linked to cognitive impairment, cardiovascular stress, impaired immune function, and disrupted metabolism (Pugh, 2007). Noise can exacerbate existing hearing loss, impede communication, and increase confusion and delirium, especially in patients with frailty or dementia. Reducing noise levels in healthcare environments has been shown to improve patient satisfaction, enhance sleep quality, and support overall health outcomes (Pugh, 2007).

Theoretical Framework

Theoretical perspectives on the impact of noise emphasize the importance of acoustic design in mitigating negative effects and promoting well-being. Theories of environmental acoustics suggest that incorporating sound-absorbing materials and effective spatial layouts is crucial in creating supportive environments for individuals with frailty and dementia. Alessi et al. (1999) highlight the role of high-quality indoor sound systems that produce soothing sounds, such as nature sounds, in reducing discomfort and anxiety. Bharathan (2007) emphasizes the importance of minimizing confusion and sensory overload through thoughtful acoustic design. The theoretical application of these concepts involves integrating noise-reducing features and sound-effect technologies into care environments. This approach aims to create serene and supportive spaces that cater to the needs of individuals with cognitive impairments and frailty (Brawley, 2001; Anderzhon et al., 2007). The integration of natural soundscapes, careful acoustic design, and the use of technology to enhance environmental quality reflect a comprehensive approach to improving well-being in care settings.

METHODOLOGY

This research is underpinned by a robust multi-method approach. This methodology was meticulously designed to provide a comprehensive and reliable assessment of the factors influencing patient care and safety in healthcare facilities. By combining subjective clinical data with objective environmental measurements, the study offers a robust framework for understanding the complex interactions between environmental conditions and patient outcomes. The findings of a comprehensive literature review were used to drive the analysis of data obtained from the 115 pilot projects funded by the Department of Health (DH) England's National Dementia Capital Investment Programme (HBN 08-02, 2015; Pantzartzis, E. et al., 2016). Over this period, the authors closely monitored the project's progress, analysed the data, and reported to the Department of Health. The evaluation from the 115 pilot projects revealed that even relatively simple, cost-effective changes to the physical environment of care can have a profound positive impact on people with dementia, as well as those using and working in the services. These changes, which include reducing agitation and distress and boosting staff morale, led to the development of a set of design principles for dementia-friendly design and evidence-based environmental assessment tools for hospital and ward environments. These tools, which are free to download, have been widely used both nationally and internationally (Waller et al., A.,2015).

This research has adopted this approach to contextualise the problem and explain how it has been addressed by analysing the design indicators and showing the performance level of the design features against the design principles within the indoor built environment.

To ensure the study on indoor comfort factors is reliable and valid, we used a careful mixed-methods approach. This approach included interviews for qualitative data and a detailed questionnaire survey for quantitative data. The study focused on fifteen healthcare facilities for people living with frailty and dementia (private), and only two provided by the government in Ibadan, which has a population of approximately 3.5 million people. This research specifically concentrated on one privately owned healthcare facility (HC1) and one government-owned healthcare facility (HC3), both located in Ibadan's high-density population region (Ogunniyi et al., 2005; Adeloye et al., 2019).

Purposive sampling is a non-probability sampling technique used in this research to select a group of people and units for analysis intentionally. This enhances sample coverage and provides a framework for analysis (Barbour RS.,2001). A total of 135 participants (75 participants for HC1 and 60 participants for HC3), including families and relatives, carers, social workers, registered nurses, and highly trained professionals who are supporting people living with frailty and dementia, were recruited from two healthcare facilities (HC1 and HC3) in this research. These participants were also considered for the interview in Ibadan, Nigeria. Utilising the collected data, we developed an Indoor Built Environment Quality of Life (IBE-QoL) model. This model created using various analytical techniques such as reliability testing, correlation analysis, and regression analysis, functions as an all-encompassing instrument for evaluating the quality of life in indoor healthcare settings (Leung et al. et al., 2019). Environmental data was compared against HC1 and HC3 healthcare facilities' incident report data. Ethical approval for the research was obtained from the respective institution's committee in charge of the private and government-owned healthcare facilities before the fieldwork started. The residents were exempted during the questionnaire survey and full-scale measurement because their health might influence their environmental perception. Hence, the instruments used were non-intrusive. As a result, the participant information sheet and consent forms have been prepared as part of the necessary documentation for the fieldwork. The on-site observations and interview questions were formulated in alignment with insights obtained from the literature review and previous research and were used for data collection. Hence, it is concerned with housing choices and potential design issues of existing healthcare facilities relating to indoor built environments and their quality of life. The study was conducted from January 2020 to January 2021.The case study is about healthcare facilities domiciled in Nigeria. Figure 1 depicts the geographical map of the study location.

Fig 1. *Map of Nigeria showing the study location*
Source: Springer Link, 2023

The methodology employed in this study was designed to rigorously assess the environmental and clinical factors influencing patient care in two healthcare facilities in Ibadan, Nigeria—one privately owned (HC1) and one government-operated (HC2). These facilities were strategically selected based on a comprehensive set of criteria, including their location, size, architectural design elements, surrounding landscape, and environmental conditions such as temperature, rainfall, natural lighting, acoustics, and indoor air quality. This selection process ensured that the study covered a wide range of variables that could potentially impact the quality of care provided in these settings.

Data Collection

Clinical Data

The primary data collection for this study was conducted over a one-year period from January 2021 to January 2022. This involved gathering clinical incident reports from both HC1 and HC2 through various sources, including families and relatives of patients, caregivers, social workers, nurses, and other healthcare professionals. The data collection process was grounded in observational methods, with questionnaires designed to capture subjective assessments of the incidents. These questionnaires were carefully crafted based on a thorough literature review to ensure that they were both relevant and comprehensive. The collected clinical data served as dependent variables in the study, representing the frequency and nature of incidents such as falls, agitation, wandering, and anxiety among patients.

Environmental Data

In addition to clinical data, the study also collected environmental data, focusing on sound levels as a key factor in indoor comfort. This aspect of the study was based on a literature review that identified sound levels as a critical environmental intervention for improving living conditions in care homes. The environmental data collected served as independent variables, providing insights into how indoor environmental factors, particularly acoustics, influenced the quality of life and the occurrence of clinical incidents in healthcare facilities. The fieldwork involved a combination of qualitative and quantitative methodologies for the evaluation of the indoor built environment. Measurements were conducted using non-intrusive equipment, covering key areas of the facilities, including bedrooms, corridors, bathrooms, toilets, dining spaces, living areas, and outdoor gardens. Additional circulation areas, such as conservatories, silent rooms, and treatment unit spaces, were also included in the assessment to ensure a comprehensive evaluation of the indoor environment. Objective measurements focused on sound levels to assess acoustics, while subjective measurements were obtained through questionnaires, interviews, and other instruments. These assessments aimed to determine the extent to which indoor environmental factors, particularly noise, affected patient behavior and well-being.

Screening and Outcome Measures

The study's outcome measures focused on four key behavioral symptoms: falls, agitation, wandering, and anxiety. These symptoms were chosen based on their relevance to the population under study and their frequent use as indicators in previous research. These measures have been used to differentiate between behavioral patterns associated with frontotemporal and Alzheimer's dementia (Levy et al., 1996), to track longitudinal changes in behavioral and psychological symptoms among elderly nursing home residents (Ballard et al., 2001), and to explore the relationship between behavioral disturbances and functional status in people living with Alzheimer's disease (Lechowski et al., 2003). The full-scale assessment was designed to capture the perspectives of families, relatives, caregivers, social workers, and other healthcare professionals regarding the challenges and issues within the healthcare facilities. This assessment aimed to identify problematic areas that might require further investigation or intervention. The questionnaire and interview process was structured to be time-efficient, with each session expected to take between 10 and 15 minutes to complete

Study Sample and Data Analysis

A total of 135 participants were involved in the study, with 75 participants from HC1 and 60 from HC2. The participant pool included families and relatives, caregivers, social workers, registered nurses, and other highly trained professionals who were directly involved in the care of individuals living with frailty and dementia. This diverse sample provided a broad perspective on the factors influencing patient care and safety in the two facilities. The sample size for the study was determined following recommendations by Jenkins et al. (2020), who advised using a minimum sample size of $N \geq 25$ to ensure the robustness of social research, particularly when conducting regressions or meta-regressions. The final sample size of 135 was deemed sufficient to meet these criteria and to provide a reliable basis for the analysis. During the fieldwork, the number of residents in each facility was also documented, with five residents in HC1 and four in HC2. The distribution of participants was as follows: In HC1, there were 75 respondents, comprising 20 families/relatives, 30 caregivers/support workers, and 25 other highly trained professionals. In HC2, there were 60 respondents, including 16 families/relatives, 24 caregivers/support workers, and 20 other highly trained professionals. This distribution ensured a comprehensive representation of the various stakeholders involved in patient care in the two facilities. The data collected through the questionnaires were later processed using SPSS software, transforming the 135 original responses into 45 samples for each facility. This transformation facilitated the analysis of both dependent and independent variables using a five-point Likert scale.

Instrumentation procedure
These instruments were utilized between June 2022 and August 2022 to monitor the independent variables, resident usage, and occupant behaviours. The instruments were non-intrusive.

Fig 1. *Hand-Held Sound Level Meter, V·RESOURCING 30~130 dB Decibel Noise Measurement Tester with Backlight Digital LCD Display for Indoor/Outdoor Uses [Max/Min/Hold Function]*

The sound level measuring device was meticulously calibrated prior to each use to ensure accuracy. For the study, sound level measurements were conducted in various locations within healthcare facilities accommodating individuals with frailty and dementia. These locations included bedrooms, corridors, bathrooms, dining spaces, living areas, and outdoor garden areas. Measurements were specifically carried out on days with no rainfall and minimal wind to avoid any external interference. The procedures for taking these measurements were as follows: The device was positioned with its measuring height fixed at approximately 0.8 meters above the ground. Measurements were taken at multiple locations within each care facility. To ensure reliability, readings were collected in triplicate at set time intervals: from 09:00 to 11:00, 14:00 to 16:00, and 18:00 to 20:00 each day. The average sound level for each time interval was computed from these triplicate measurements. These averaged values were then used for further analysis. Each measurement session lasted for 15 minutes, following the methodology outlined by Taheri et al. (2019).

Fig 2. *Sound pressure level measurement (Corridor)*

In assessing the sound levels, the microphone of the sound level meter was positioned at least 3 meters from reflective surfaces such as walls and 1.5 meters above the ground. Additionally, a distance equivalent to the length of an arm from the operator's body was maintained. An error margin of up to 6 dB is considered negligible in these evaluations. Measurements were taken on days without precipitation and with minimal wind to ensure accuracy. Each measurement session at every location lasted for 30 minutes.

According to the ASHRAE Fundamentals Handbook on Sound and Vibration, predicting people's responses to sound in healthcare facilities involves acknowledging that sound is a statistical concept and may not always accurately reflect individual reactions. This is due to the influence of the listener's changing attitudes on their physiological and psychological response to sound. For instance, sounds that are perceived as excessively loud or unpleasant can negatively impact individuals' comfort levels (ASHRAE, 2013).

Sound level standards are established based on descriptors that account for both the level and spectrum of sound. Generally, sound levels below Noise Criteria (NC) or Room Criteria (RC) 35 are deemed acceptable as they do not compromise speech intelligibility. Levels at or above this threshold may disrupt or obscure speech. Moreover, even if background noise from occupancy significantly exceeds the expected sound level from mechanical equipment, the sound design target should not be adjusted to match the higher occupancy noise levels. This approach helps prevent the need for individuals to raise their voices uncomfortably to be heard over the ambient noise (ANSI, 2008; ASHRAE, 2013).

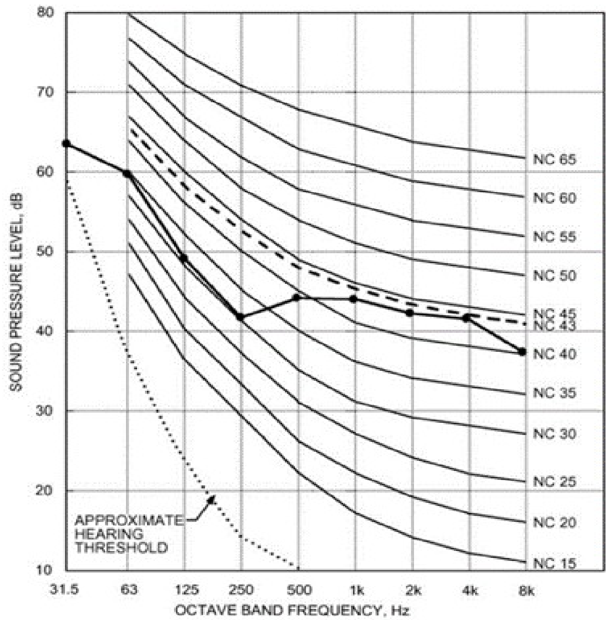


Fig 3. *Noise Criteria Curves and Sample Spectrum (Curve with Symbols)*
Source: ASHRAE, Fundamentals Handbook-Sound and Vibration (2013)

Ethical Considerations

Ethical considerations were a critical component of this study. Informed consent was obtained from all participants before their involvement in the research. The consent process ensured that participants were fully aware of the study's objectives, their role in the research, and their rights as participants. This approach not only adhered to ethical standards but also ensured the validity and reliability of the data collected.

RESULTS AND DISCUSSIONS

Table 1. *Average decibel levels for everyday sounds*

Sound Frequency	***Sound Level in dB(A)***	***Sound Source***
Faint - Safe listening for any period	30	whisper, quiet library
Moderate - Safe listening for any period	40	quiet room
	50	moderate rainfall
	60	typical conversation, dishwasher, clothes dryer
	70	group conversation, vacuum cleaner, alarm clock
Very loud - Dangerous to hearing; wear earplugs or earmuffs	91	subway, passing motorcycle, gas mower
Extremely loud - Dangerous to hearing; wear earplugs or earmuffs	94	hair dryer, kitchen blender, food processor
	100	tractor, listening with earphones
	106	gas leaf blower, snow blower
	112	maximum output of some MP3 players, rock concerts, and chainsaws.
Painful, steady noise - Not safe for any period	120	jet plane take-off, siren, pneumatic drill
	130	jackhammer
Painful impulse noise - Not safe for any period	140	firearms
	150	fireworks at 3 feet, firecracker, shotgun

In the context of a hospital, adhering to WHO standards for noise levels is crucial to ensure the safety and well-being of both patients and staff. Table 1 outlines the average sound levels associated with everyday activities, categorized according to their potential impact on hearing as defined by World Health Organization (WHO) standards. The table ranges from "Faint" to "Painful," each representing an increasing risk to hearing with higher sound levels.

At the lowest level, categorized as "Faint," sounds are considered very safe and pose no risk to hearing, regardless of how long one is exposed. For instance, a whisper or the environment of a quiet library typically registers around 30 dB(A). Moving up to the "Moderate" category, sounds remain safe for extended exposure without risking hearing damage. A quiet room, for example, produces about 40 dB(A), while moderate rainfall is around 50 dB(A). Everyday activities such as typical conversations, the operation of dishwashers or clothes dryers, and group conversations generally produce sound levels between 60 and 70 dB(A). Other examples in this category include the noise from a vacuum cleaner or an alarm clock.

In the "Very Loud" category, sound levels become potentially harmful with prolonged exposure, necessitating the use of protective measures like earplugs or earmuffs. For example, the noise from a subway, a passing motorcycle, or a gas-powered lawnmower typically reaches around 91 dB(A). As sound levels rise further into the "Extremely Loud" category, the risk of hearing damage increases significantly, making ear protection essential. Sounds in this range include the noise from a hair dryer, kitchen blender, or food processor at around 94 dB(A). The operation of a tractor or the use of earphones at high volumes can reach 100 dB(A), while the sound from a gas leaf blower or snow blower can reach 106 dB(A). Some MP3 players at maximum volume, rock concerts, and chainsaws can produce sound levels as high as 112 dB(A). At the highest end of the scale, categorized as "Painful," the noise is so intense that it is not safe to be exposed without protection for any period. Continuous noise at this level includes a jet plane taking off, a siren, or a pneumatic drill, all producing around 120 dB(A). Impulse noises, such as those from a jackhammer at 130 dB(A), firearms at 140 dB(A), and fireworks or shotguns at 150 dB(A), are especially hazardous.

Table 2: *Field Measurement of Sound Level Db(A) - Healthcare Facility 1 (HC1) – (Private)*

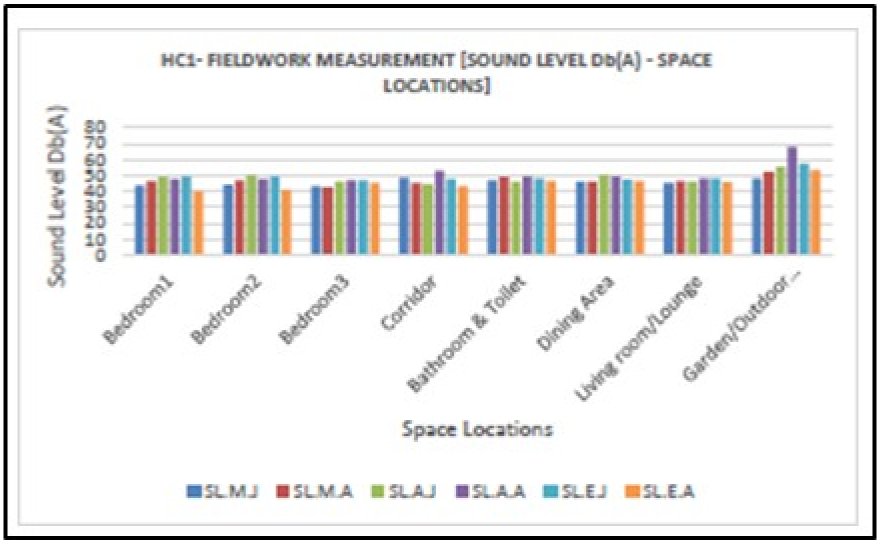
Healthcare Facility 1	**Sound level**					
	Morning		**Afternoon**		**Evening**	
	June	**August**	**June**	**August**	**June**	**August**
Bedroom1	43.45	46.20	48.90	47.58	49.05	40.20
Bedroom2	43.88	46.73	50.18	47.68	49.13	40.73
Bedroom3	43.37	42.43	46.17	46.98	46.97	45.28
Corridor	48.35	45.13	44.40	53.03	47.68	43.20
Bathroom & Toilet	46.93	48.85	46.08	49.08	47.93	46.25
Dining Area	46.12	46.16	50.10	49.38	47.12	46.25

Living room/Lounge	45.15	46.65	45.90	48.18	48.00	45.50
Garden/Outdoor Space	48.13	52.13	55.40	67.78	57.10	53.33

The field measurements of sound levels in Healthcare Facility 1 (HC1), a private healthcare facility shown in Table 1 reveal variations in noise levels across different spaces and times of day during the months of June and August. The data highlights that noise levels generally fluctuate within a similar range in most indoor spaces, with the garden/outdoor space exhibiting the most significant variations.

The sound levels in bedrooms 1, 2, and 3 remain relatively consistent across the measurement periods, with slight increases observed in the morning and afternoon during August compared to June. The evening measurements show a notable decrease in August, particularly in Bedroom 1 (40.20 dB(A)) and Bedroom 2 (40.73 dB(A)), contrasting with the higher levels recorded in June. The corridor shows an interesting pattern, with the morning sound levels decreasing from 48.35 dB(A) in June to 45.13 dB(A) in August, while the afternoon levels show a substantial increase from 44.40 dB(A) in June to 53.03 dB(A) in August. Evening measurements demonstrate a decrease in August (43.20 dB(A)) compared to June (47.68 dB(A)).

Sound levels in the bathroom and toilet areas are higher in August compared to June across all periods. The morning sound level rises slightly from 46.93 dB(A) in June to 48.85 dB(A) in August, with similar upward trends observed in the afternoon and evening. The dining area maintains relatively stable sound levels with minor increases in the afternoon and evening measurements for both months. The highest sound levels are recorded in the afternoon (50.10 dB(A) in June and 49.38 dB(A) in August). The living room/lounge shows modest variations in sound levels between June and August, with a slight increase during the afternoon in August (48.18 dB(A)) and evening (48.00 dB(A)) compared to June. The garden/outdoor Space exhibits the most significant fluctuation, particularly in the afternoon, where sound levels surge from 55.40 dB(A) in June to 67.78 dB(A) in August. This outdoor area also shows elevated levels during the morning and evening in August compared to June, reflecting greater variability in noise exposure in this external environment. Overall, the results indicate that while indoor areas in HC1 maintain relatively consistent sound levels with minor seasonal variations, the outdoor environment is subject to more substantial fluctuations, particularly during the afternoon in August. These findings suggest the need for targeted noise management strategies, especially in outdoor areas, to maintain a comfortable acoustic environment for occupants.



***Key:** SL.M.J= Sound level.Morning. June; SL.M.A= Sound level. Morning. August; SL. A. J= Sound level.Afternoon. June; SL.A.A= Sound level.Afternoon. August; SL.E.J= Sound level. Evening. June; SL.E. A= Sound level. Evening. August*

Fig 3. *Fieldwork measurement showing Sound Level Db(A) against the Space locations (HC1)*

Figure 3 shows the fieldwork measurement of the sound level dB(A) of HC1 facilities, the time of incidents (morning: 0800 hrs to 1159 hrs, afternoon: 1200 hrs to 1659 hrs, evening: 1700 hrs to 2059 hrs), and their locations of incidents (Bedrooms 3: Bathroom and Toilet, Corridor, Dining Area, Living Room, and Lounge). According to the fieldwork measurement, the top three locations with the highest noise average decibel levels for sound are the corridor, which had a maximum sound level dB(A) of 53.03 dB(A) in August 2022; the bedroom, with a maximum sound level dB(A) of 50.18 dB(A) in June 2022; and the dining area, with a maximum sound level dB(A) of 50.10 dB(A) in June 2022. All these sound levels are below Noise Criteria (NC) or Room Criteria (RC) 35 and are generally not detrimental to good speech intelligibility. Also, the average decibel levels for sounds around these three locations are moderate and safe for listening at any time (see Table 2).

Table 3: Fieldwork- Measurement - Sound Level Db(A) - Healthcare Facility 2 (HC2) (Government)

Healthcare Facility 2	Sound level					
	Morning		Afternoon		Evening	
	June	August	June	August	June	August
Bedroom1	46.45	47.2	58.96	57.58	49.05	43.2
Bedroom2	46.88	47.73	56.18	57.68	49.13	43.73
Bedroom3	46.37	47.43	56.17	56.98	46.97	45.28
Corridor	49.35	55.13	67.4	63.03	57.68	56.2
Bathroom & Toilet	43.93	48.85	46.08	43.08	47.93	44.25
Dining Area	46.12	47.16	54.1	54.38	48.12	46.34
Living room/Lounge	47.15	55.65	61.9	58.18	54	55.5

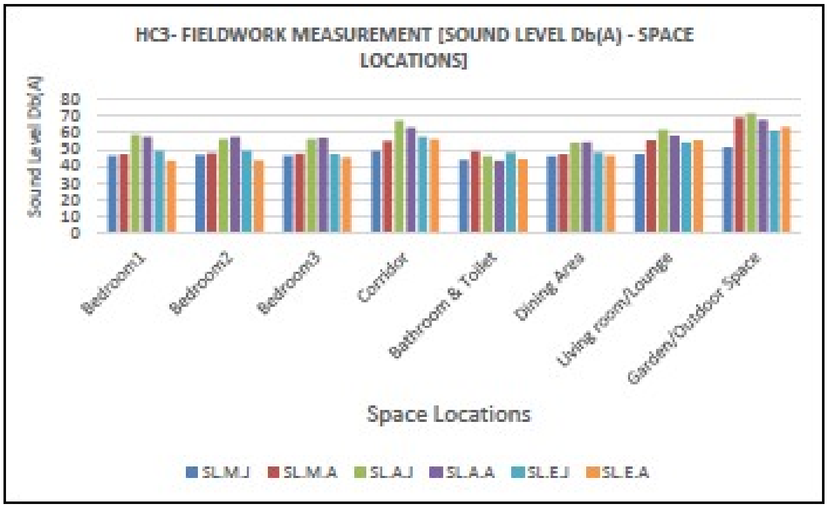
Garden/Outdoor Space	51.13	69.13	71.4	67.78	61.1	63.33

The data from Healthcare Facility 2 shows varying sound levels across different times of day—morning, afternoon, and evening—measured in June and August. In the morning, most areas experienced a slight increase in sound levels from June to August. The Garden/Outdoor Space notably had the most significant rise, with sound levels jumping from 51.13 dB in June to 69.13 dB in August. Other areas, such as the Corridor and the Living room/Lounge, also saw noticeable increases in the morning.

During the afternoon, sound levels were generally higher across the facility compared to the morning and evening, suggesting increased activity during this period. The Corridor and Garden/Outdoor Space were the loudest areas, with the Garden/Outdoor Space reaching a peak of 71.4 dB in June. However, there was a slight reduction in afternoon sound levels from June to August in most areas, except for Bedroom 2, where the noise levels slightly increased. In the evening, sound levels tended to be lower than those in the afternoon, indicating a quieter environment as the day progressed. The Garden/Outdoor Space and the Living room/Lounge were the noisiest areas during this time, but both saw a decrease in sound levels from June to August. The bedrooms generally became quieter in August, with Bedroom 1 experiencing a significant reduction in sound levels from 49.05 dB in June to 43.2 dB in August.

Examining specific areas, the bedrooms (Bedroom 1, 2, and 3) showed relatively stable sound levels in the morning, with slight increases in August. The afternoon levels were higher but decreased in the evening, especially in August, indicating a quieter night environment. The Corridor saw a substantial increase in morning sound levels, while the Bathroom & Toilet had higher morning noise that reduced in the afternoon and evening by August. The Dining Area showed consistent sound levels throughout the day with only minor changes, whereas the Living room/Lounge experienced a noticeable rise in morning noise levels from June to August. Finally, the Garden/Outdoor Space consistently had the highest sound levels, particularly in the morning and afternoon, with significant increases observed in August.

The sound levels within Healthcare Facility 2 vary by time of day and month, with August generally showing an increase in morning noise, particularly in common areas like the Corridor, Living room/Lounge, and Garden/Outdoor Space. However, the facility tends to quiet down in the evening, especially in the bedrooms, indicating efforts or natural tendencies towards creating a calmer environment later in the day.



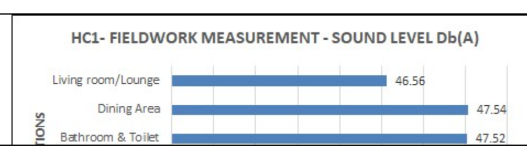
Key:

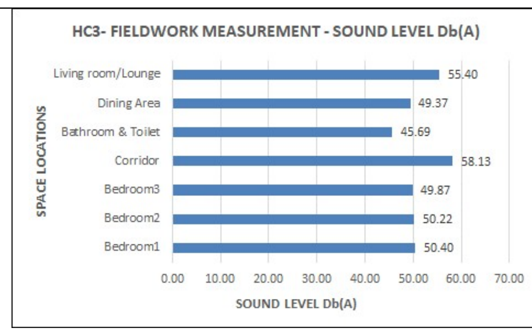
SL. M. J= Sound level. Morning. June SL. M. A= Sound level. Morning. August
SL. A. J= Sound level. Afternoon. June SL. A. A= Sound level. Afternoon. August
SL. E. J= Sound level. Evening. June SL.E. A= Sound level. Evening. August

Fig 4 Fieldwork measurement showing Sound Level Db(A) against the Space locations (HC2)

Figure 4 shows the fieldwork measurement of the sound level dB(A) of HC2 facilities, the time of incidents (morning: 0800 Hrs to 1159 Hrs, afternoon: 1200 Hrs to 1659 Hrs, evening: 1700 Hrs to 2059 Hrs), and their locations of incidents (Bedrooms-3, Bathroom and Toilet, Corridor, Dining Area, Living Room, and Lounge). According to the fieldwork measurement, the top three locations with the highest noise average decibel levels for sound are: the corridor, which had a maximum sound level dB(A) of 67.40 dB(A) in the month of June 2022; the living room and lounge, with a maximum sound level dB(A) of 61.90 dB(A) in the month of June 2022; and the bedroom, with an average maximum sound level dB(A) of 58.90 dB(A) in the month of June 2022. All these sound levels are above Noise Criteria (NC) or Room Criteria (RC) 35 and may interfere with or mask speech (see Fig. 5.3). Also, the average decibel levels for sounds around these three locations are moderate and could be safe for listening at any time (see table 5.3). Please note that garden and outdoor spaces were not considered part of interior spaces in these circumstances.

Table 4: Summary of findings from Fieldwork - Measurement Sound Level Db(A)

	Healthcare Facilities	***Incidents Report Variables***	***Types of Intervention***	***Sound Level Db(A)***
X				
HC1 – Private	Bedroom1	F=4; Ag=2 Ax=7; RM=1	Non-Pharmacology	
	Bedroom2			

	Bedroom3	W=1	interventions = 20 times (include massage therapy, design of environment, relocation, exercises and/or stretching, or combinations of these treatments, the physiotherapist selected the interventions to be implemented based on their clinical expertise). - Pharmacology interventions = 11 times (include medication to be implemented based on their clinical expertise).	
	Bathroom & Toilet	HI=2; SI=1 IB=1; W=1		
	Corridor	F=1; C=1 Ag=2; Ax=1 PA=1 VA=2; W=5		
	Dining Area	Ag=1		HC1- **Note:** Fall (F), Collapse (C), Risk of Choking (RC), Head Injury (HI), Agitation (Ag), Self-Injury (SI), Anxiety (Ax), Road Accident (RA), Physical Aggression (PA), Verbal Aggression (VA), Inappropriate Behaviour (IB), Refusal of Medication (RM), Wandering (W), Slip (S)
	Living room/Lounge	F=1; RC=1		
	Garden/Outdoor Space	SI=1; VA=1 S=2		
HC2 – Government	Bedroom1	F=1; Ag=1 Ax=1; VA=1 RM=1 W=3; S=1	Non-Pharmacology interventions = 37 times (include massage therapy, design of environment, relocation, exercises and/or stretching, or combinations of these treatments, the physiotherapist selected the interventions to be implemented based on their clinical	
	Bedroom2			
	Bedroom3			
	Bathroom & Toilet	F=1; C=1 HI=1; Ax=1 VA=1; IB=1 W=2; S=1		
	Corridor	F=1; Ax=1 PA=1; VA=2 W=1		HC2 - **Note:** Fall (F), Collapse (C), Risk of Choking (RC), Head Injury (HI), Agitation (Ag), Self-Injury (SI), Anxiety (Ax), Road Accident (RA), Physical Aggression (PA), Verbal Aggression (VA), Inappropriate Behaviour (IB), Refusal of
	Dining Area	No incident reported		
	Living room/Lounge	F=2; Ag=2 Ax=2; PA=1 VA=1; IB=1 RM=3; W=1 S=1		

	Garden/Outdoor Space	F=1; Ag=1 Ax=1; PA=2 VA=1; RM=1	expertise). - Pharmacology interventions = 8 times (include medication to be implemented based on their clinical expertise).	Medication (RM), Wandering (W), Slip (S)

The analysis of incident reports from two healthcare facilities—HC1, a private institution, and HC2, a government-run hospital—provides important insights into the frequency and nature of various incidents, the types of interventions used to manage these incidents, and the potential impact of sound levels on patient behaviour and safety.

The data reveals that both HC1 and HC2 experienced a range of incidents, though the frequency and types varied across different areas within the facilities. In HC1, the most incident-prone areas included the Bathroom & Toilet, Corridor, and Garden/Outdoor Space. These areas recorded multiple incidents such as falls (F), agitation (Ag), self-injury (SI), verbal aggression (VA), and slips (S). For example, in HC1, the Bathroom & Toilet area had incidents of head injury (HI), self-injury, inappropriate behaviour (IB), and wandering (W), indicating that this space is particularly hazardous. Similarly, the Corridor in HC1 saw a mix of falls, agitation, physical aggression (PA), and verbal aggression, making it a hotspot for varied incidents.

In contrast, HC2 showed a different distribution of incidents, with Bedroom 1 and the Bathroom & Toilet being the most problematic areas. In Bedroom 1 of HC2, incidents included falls, agitation, anxiety (Ax), verbal aggression, and wandering. The Bathroom & Toilet in HC2 similarly recorded incidents of falls, head injury, anxiety, verbal aggression, and inappropriate behaviour, mirroring some of the patterns observed in HC1 but with a different emphasis on certain types of incidents. The types of incidents across both facilities suggest that patient agitation, aggression (both physical and verbal), and wandering are common issues that need to be managed effectively. Falls are another significant concern, particularly in areas like bathrooms and corridors, where the risk of slipping or tripping is higher due to the nature of the environment.

One of the key findings from the data is the predominant use of non-pharmacological interventions in managing incidents across both HC1 and HC2. In HC1, non-pharmacological interventions were used 20 times, while pharmacological interventions were employed 11 times. Similarly, in HC2, non-pharmacological methods were utilized 37 times compared to just 8 instances of pharmacological intervention. Non-pharmacological interventions included a variety of approaches such as massage therapy, environmental design changes, relocation, and exercises or stretching. These interventions were selected based on the clinical expertise of the physiotherapists and were tailored to meet the specific needs of the patients. For example, in cases of agitation or aggression, massage therapy or environmental changes might be implemented to create a more calming and less stimulating environment, thereby reducing the likelihood of further incidents.

The heavy reliance on non-pharmacological interventions reflects a growing recognition of the importance of holistic, patient-centered care in managing behavioural and psychological symptoms in healthcare settings. These interventions are not only effective in addressing immediate incidents but also in promoting long-term well-being by reducing the reliance on medications, which can have side effects and may not always address the root cause of the behaviour. Pharmacological interventions, while less frequently used, played a crucial role in cases where immediate symptom management was necessary, or where non-pharmacological methods were insufficient. Medications were administered based on clinical judgment, often in conjunction with other therapeutic approaches to provide a comprehensive treatment plan. The data suggests that while non-pharmacological methods are preferred, there is still a need for pharmacological interventions in certain situations to ensure patient safety and comfort.

The data also hints at a potential link between sound levels within the facilities and the frequency or type of incidents. Although sound levels in specific areas were not directly correlated with incidents in this dataset, the existing research indicates that noise can significantly impact patient behaviour, particularly in sensitive environments like hospitals. High noise levels can contribute to increased stress, agitation, and confusion, particularly in vulnerable populations such as the elderly or those with cognitive impairments. In the context of HC1 and HC2, areas with higher sound levels, such as corridors and outdoor spaces, may create environments that exacerbate certain behaviours like agitation, wandering, or aggression. For instance, the garden/outdoor space in HC1, which likely experiences variable and potentially high noise levels due to environmental factors, was associated with incidents of self-injury and verbal aggression, as well as slips. These behaviours could be linked to the stress or disorientation caused by fluctuating sound levels in this space. Similarly, the Corridor in HC1, which saw a range of incidents including falls, physical aggression, and verbal aggression, may also be influenced by the acoustic environment. In healthcare settings, corridors often serve as high-traffic areas with significant noise from foot traffic, equipment, and conversations, which can contribute to sensory overload and trigger adverse behaviours in patients.

Conclusion

The study highlights the importance of maintaining noise levels within the "Moderate" range (40-70 dB(A)) in areas like patient rooms to promote a calm and healing environment. Higher noise levels, particularly those in the "Very Loud" or "Painful" categories, can be detrimental, emphasizing the need for effective noise management strategies in healthcare settings. Field measurements in the study show that the sound levels at the HC1 and HC2 healthcare facilities generally do not hinder speech intelligibility, with average decibel levels being moderate and safe for listening. However, these facilities lack acoustic privacy due to the absence of sound-absorbent materials and finishes. Noise exposure in these environments has been linked to health issues like headaches, loss of focus, and irritation. Sound-absorbent materials should be used to promote a quieter and more restful setting on surfaces to improve the acoustic environment. In a bid to attain this, it is recommended to:

- Hospitals should consider conducting regular assessments of noise levels in different areas and implementing sound management strategies where necessary. This might include the use of sound-absorbing materials, designing quieter spaces, and controlling sources of noise to create a more calming and less disruptive environment for patients.
- Keep background noise below 60 decibels.
- Encourage using sound-absorbing materials such as acoustic ceiling tiles, wall hangings, and curtain fabrics.
- Utilize low-frequency alarms and auditory cues suitable for people with hearing impairments.
- Provide custom-designed solutions for visual and auditory memory stimulation.
- Use sound-absorbing barriers like strategically planted shrubs and trees to reduce outdoor noise around the facilities.
- Also, enhancing the design of the spaces investigated to reduce hazards, such as installing non-slip flooring, improving lighting, and implementing clear signage, could help prevent incidents like falls and reduce agitation.
- Addressing the underlying causes of behaviours through environmental modifications, physical therapy, and other non-invasive methods, healthcare providers can reduce the reliance on medications and improve patient outcomes. However, it is essential to recognize that pharmacological interventions remain a necessary component of care for certain patients and situations, particularly when non-pharmacological methods alone are insufficient.

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