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Article

A multi-loci time-series descriptive study on noise levels in a pediatric emergency care department

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Abstract:
Objective: To investigate the status of the acoustic environment of a typical Chinese pediatric emergency care department in a time series and identify the relationship between noise levels and factors such as crowd density and movement. **Methods**: A descriptive study was designed based on a multi-loci time-series method. We measured three loci under three variable settings: the decibel value, observation volume, and emergency care volume. **Results**: The noise levels of the three loci were significantly higher than the internationally recommended levels, exceeding rate reached more than 86.3%. The 24-hour mean map of the three loci showed similar fluctuation patterns, all of which had two peaks at approximately 10:00 AM and 16:00 PM. **Conclusions**: The daytime and nighttime noise levels were well-fitted by cubic functions with different coefficients. It is suggested that crowd density and movement may play important roles in noise mean fluctuations, which can be optimized to ensure a satisfactory environment in a pediatric emergency care department.

Keywords: Nursing, Noise, Hospital Noise Pollution, Pediatric Emergency, Environmental Stressors, Decibel Value, Observation Volume, Emergency Care Volume

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1. Introduction

Noise is perceived as an environmental stressor and nuisance [1] and has a common negative effect on the pediatric system [2-4]. Pediatric noise pollution is particularly noticeable owing to the client's early age, and children are particularly vulnerable to the health effects of noise [5]. The study showed that children exposed to high noise levels may develop feelings of irritability and suffer poor health, which impair cognitive development [6]. In addition, noise exposure can cause physical and psychological discomfort such as hearing impairment, insomnia, cardiovascular stress response, and psychological disorder [1,5]. Systematic exposure to sound pressure above the recommended level can decrease the speed and quality of recovery [2,4]. Noise exposure can also result in lower work efficiency for employees [2,4]. Therefore, noise levels in hospitals should be continuously monitored and measured.

Several studies showed that noise pollution in the pediatric department may have involvement in sources of human and machine [7]. In practice, with technological advances in hospital equipment and construction processes, noise from medical devices rarely exceeds allowable limits by OSHA (Occupational Safety and Health Administration) and NIOSH (National Institute for Occupational Safety and Health) [8]. While, noise levels during crying episodes exceeded the limits and reached maximum levels of 112.9 dB(A) [4,9]. On the other hand, human activities, such as talking, are often identified as the most frequent source of noise [10]. Unlike operating rooms and intensive care units, the number of pediatric outpatients fluctuates with time and has certain randomness. And the number of patients in pediatric emergency care department has obvious characteristics of time regularity [11]. However, through a limited review of the literature, we have found that studies often overlook human activities [8,12]. It would be meaningful to explore the relationship among the noise value, the number in the pediatric emergency care room, noise exposure and client number. However, to the best of our knowledge, no study has investigated the alterations of client number and noise value. This study aims to address this problem by exploring the similar wave rules of noise value in time dimension groups and altering the noise value including maximum, minimum, and mean in different groups.

2. Materials and Method

2.1. Evaluation location of pediatric emergency care department

Noise assessment was performed in pediatric emergency care rooms in tertiary first-class hospitals.

The second floor of the building can be divided into inner and outer areas using a square circular corridor equipped with six high-rise elevators, two low-rise elevators, and two stairs. There are open pediatric infusion observation areas, blood collection areas, drug allocation rooms, drug storage areas, doctors' offices, staff rest areas, and garbage disposal areas.

2.2. Evaluation personnel mobility of pediatric emergency care department

The basic nursing team and staff work eight hours in hospital shifts: day shift (08:00-12:00, 15:00-18:00), afternoon shift (18:00-01:00), and night shift (01:00-08:00).

The visiting process guides personnel mobility, and patients usually wait in the waiting area at approximately 7:00. After receiving the doctor's examination application, the crowd gradually dispersed into the observation area of the sample collection and laboratory. After obtaining the test results at 02:30 pm, they gradually returned to the waiting room for further consultation. According to the patient's condition, some patients go home for treatment, whereas others remain in the hospital.

2.3. Noise exposure limitation

The US Environmental Protection Agency (EPA) recommended that the daytime (08:00am-06:00pm) sound level should be lower than 45 dB (A) and the nighttime (06:00 pm-08:00 am) sound level should be lower than 35 dB (A) [13]. The risk of noise exposure in pediatric hospital patients at an American college supported EPA's recommendation and emphasized that noise levels over 45 dB (A) may lead to cochlear injury or disruption [14]. The World Health Organization recommends that patient treatment rooms should not exceed 35 dB (A) [15].

According to the Acoustic Environmental Quality Standard (GB 3096-2008) [16], pediatric emergency clinic and emergency treatment rooms in China are mainly medical and health functions. It belongs to the first level of the acoustic environment function area and stipulates a daytime noise limit of 55 dB (A) and night noise limit of 45 dB (A) [17]. The environmental quality level of urban areas can be divided into five levels based on environmental noise monitoring technical specification for Urban acoustic environment conventional monitoring (HJ 640-2012): "excellent" (day value≦50.0 dB (A), night value≦40.0 dB (A)), "good" (day value≦55.0 dB (A), night value≦45.0 dB (A)), "general", "poor" and "range" [18]. The acoustic environmental quality level of pediatric emergency cares and emergency treatment rooms should be maintained above the second level, that is, the "better" level.

Hospital buildings should provide good acoustic comfort to users and comply with current regulations. However, there are no specific guidelines for pediatric nursing units based on acoustic comfort.

2.4. Measurement and Methodology

The product model of the sound-level instrument was SNDWAY SW-525B. The equipment was calibrated using a certification authority. The accuracy of the SNDWAY SW-525B noise meters is ±1.5 dB, and the measurement frequency is set at 2 seconds, providing a detailed and continuous record of noise levels. The frequency-weighting method employed by the meters conforms to standard practices, ensuring the collected data is comparable and relevant. Three SNDWAY SW-525B noise meters were installed on the wall of the pediatric emergency care department, which was located in the puncture operation table, observation infusion area, and waiting area. The markers used were Loci 1, 2, and 3. The installation points of the noise gauges were carefully selected to minimize interference and ensure accurate measurements. The meters were installed at a height of over 1.2 meters from the ground, ensuring they were not obstructed by patients or equipment. Additionally, they were positioned 0.5 meters away from any potential reflectors, such as walls or large pieces of furniture, to avoid skewed readings due to reflected sound. Furthermore, the meters were placed at least 1 meter away from outer windows to minimize the impact of external noise sources.The noise values in the pediatric emergency room were collected at a third-class A-level hospital in Hunan Province from January 2018 to October 2018. During data collection, the noise meters operated continuously, capturing a comprehensive dataset of noise levels in the pediatric emergency care department. This methodology ensured that the collected noise data was accurate, reliable, and representative of the actual noise environment in the department. Additionally, the tools are calibrated every morning at 8:00 AM, checking for sufficient battery life, normal operation, and other relevant aspects.

2.5. Statistical analysis

The data were statistically analyzed using SPSS 18.0. The P-P plot and Q-Q plot both confirm that all data adhere to a normal distribution. Noise values at different time points were expressed as the mean and standard deviation. A single-sample *t*-test was used to compare the mean noise of each point with the limited daytime and nighttime values. The cubic model in curve fitting was used to establish the relationship between the number of visitors and mean noise. We reported the coefficient of the cubic term to indicate the strength and direction of the relationship, the r^2 value to measure the model's explanatory power, and the F-statistic and p-value to test the significance of the model. The results were considered statistically significant at $p < 0.05$.

3. Results

3.1. Sound levels of daytime and nighttime

The installation sites included the puncture, observation infusion, and waiting areas, corresponding to loci 1, 2, and 3, respectively. The values of noise means exceeding the comparative index (daytime value>55.0 dB (A) and nighttime value>45.0 dB (A)) were divided into the exceeding group, and the exceeding rate of each group was calculated. The noise values of the day and night groups were tested by using a single-sample t-test with comparative indicators. Table 1 presents the results.

The results in Table 1 show that daytime and nighttime noise pollution in the wards exceeded the standard, and the lowest rate was 86.3%. In addition, all noise means were higher than the values recommended by several agencies (the EPA of China and the US).

Table 1. Sound Level and Over-standard Rate

time	loci	N	Mean (dB (A))	*t*	*p*	Rate(%)
daytime	**1**	8364713	72.1±8.6	5726.981	<0.01	95.5
	2	8431530	72.9±8.5	6164.885	<0.01	95.9
	3	8110336	72.8±9.6	5293.539	<0.01	95.5
	subtotal	24906579	72.6±8.9	9873.708	<0.01	95.6
nighttime	**1**	4182547	55.4±9.8	2170.123	<0.01	86.3
	2	4220908	56.6±9.2	2583.953	<0.01	95.4
	3	4000424	54.8±7.4	2654.917	<0.01	97.1
	subtotal	12403879	55.6±8.9	4191.907	<0.01	92.9

3.2. Noise source intensity

According to the observations, there are five main variables related to noise: crying, instrument alarm, clinical manipulation, ringtone, and conversation. The highest noise source was crying and the lowest noise source was ringtone, as shown in Table 2.

Table 2. Intensity of noise sources in wards

Variables	Content	Mean±SD (dB (A))
Crying	Fear, anxiety, resistance to crying	86.75±9.12
Instrument alarm	ECG monitor, infusion pump, atomizer	73.42±7.42
clinical manipulation	Rescue, atomization, sputum aspiration and venipuncture	72.40±10.91
Ringtone	fixed telephone	65.87±4.01
conversation	Medical workers, children, companions, cleaners, security personnel	78.64±6.73

3.3. Sound levels of hours

Table 3 presents the details of the sound levels at the three loci at 24 h. The time to enter and exit the peak for locus 3 was respectively one hour earlier than those for loci 1 and 2, which may be related to the direction of circulation and activity (Figure 1). Patients in the waiting areas at locus 3 gradually moved towards the puncture operation area at locus 1 and the observation area at locus 2 based on the treatment process.

Table 3. The sound levels of 24 hours

Hour	Loci	Mean (dB (A))	Std. Error	Lower Bound (dB (A))	Upper Bound (dB (A))
0	1	57.562	0.010	57.541	57.582
	2	58.525	0.010	58.505	58.546
	3	55.623	0.011	55.602	55.644
1	1	53.970	0.010	53.949	53.990
	2	55.357	0.010	55.337	55.378
	3	53.699	0.011	53.678	53.719
2	1	52.112	0.010	52.092	52.133
	2	53.639	0.010	53.619	53.660
	3	52.567	0.011	52.546	52.587
3	1	50.890	0.010	50.870	50.910
	2	52.569	0.010	52.549	52.589
	3	51.606	0.011	51.585	51.627
4	1	50.719	0.010	50.699	50.739
	2	52.340	0.010	52.319	52.360

	3	51.527	0.011	51.506	51.547
5	1	55.822	0.010	55.802	55.842
	2	55.938	0.010	55.918	55.959
	3	54.840	0.011	54.819	54.861
6	1	57.680	0.010	57.660	57.701
	2	57.735	0.010	57.714	57.755
	3	62.363	0.011	62.343	62.384
7	1	67.404	0.010	67.384	67.424
	2	66.599	0.010	66.579	66.619
	3	73.879	0.011	73.859	73.900
8	1	74.066	0.010	74.046	74.086
	2	73.548	0.010	73.528	73.568
	3	77.838	0.010	77.818	77.859
9	1	76.360	0.010	76.340	76.381
	2	76.556	0.010	76.536	76.577
	3	79.390	0.010	79.370	79.411
10	1	77.222	0.010	77.202	77.243
	2	77.961	0.010	77.941	77.982
	3	79.474	0.010	79.453	79.494
11	1	76.900	0.010	76.880	76.920
	2	78.003	0.010	77.983	78.023
	3	76.445	0.010	76.425	76.466
12	1	74.930	0.010	74.910	74.951
	2	76.638	0.010	76.618	76.659
	3	73.252	0.010	73.232	73.273
13	1	73.862	0.010	73.841	73.882
	2	75.532	0.010	75.512	75.552
	3	75.491	0.010	75.471	75.512
14	1	74.831	0.010	74.810	74.851
	2	75.861	0.010	75.841	75.882
	3	77.985	0.011	77.965	78.006
15	1	76.043	0.010	76.023	76.063
	2	76.648	0.010	76.627	76.668
	3	77.390	0.010	77.369	77.411
16	1	75.322	0.010	75.301	75.342
	2	76.218	0.010	76.197	76.238
	3	75.400	0.010	75.379	75.421
17	1	73.680	0.010	73.660	73.700
	2	74.927	0.010	74.907	74.947
	3	71.426	0.010	71.405	71.447
18	1	70.726	0.010	70.706	70.747
	2	72.483	0.010	72.463	72.504
	3	67.496	0.011	67.475	67.516
19	1	69.741	0.010	69.720	69.761
	2	71.342	0.010	71.322	71.362
	3	67.223	0.011	67.202	67.244
20	1	68.678	0.010	68.657	68.698
	2	70.054	0.010	70.033	70.074
	3	66.144	0.011	66.123	66.164
21	1	65.529	0.010	65.509	65.550
	2	67.051	0.010	67.031	67.071
	3	63.564	0.011	63.543	63.584

22	1	62.242	0.010	62.221	62.262
	2	63.642	0.010	63.622	63.662
	3	60.302	0.011	60.281	60.323
23	1	59.833	0.010	59.813	59.853
	2	60.940	0.010	60.920	60.960
	3	58.015	0.011	57.994	58.035

For the 24-hour noise mean distribution map, multiple linear regression was used to calculate the formula. We can obtain a cubic model: $Y= 0.0018x^4 - 0.0908x^3 + 1.3018x^2 - 3.8109x + 55.897$， $r^2 = 0.915$.

As shown in Figure 1, both loci exhibit the same rhythm. There were two troughs and two peaks at all the three loci. The fluctuation rhythms of loci 1 and 2 are more appropriate. Except for the noise value at 7:00 and 8:00, the mean value of locus 2 was higher than that of locus 1, which might be related to the longer time children spent in the observation room. The peak times of entry and exit for locus 3 were earlier than those for loci 1 and 2 were. This is related to the waiting area of locus 3. The patient's visiting procedure involved seeing a doctor in the waiting area before transferring to the puncture area at Site 1 and the observation area at Site 2. The fluctuation rhythm of the mean noise at each point reflects the direction of crowd activity.

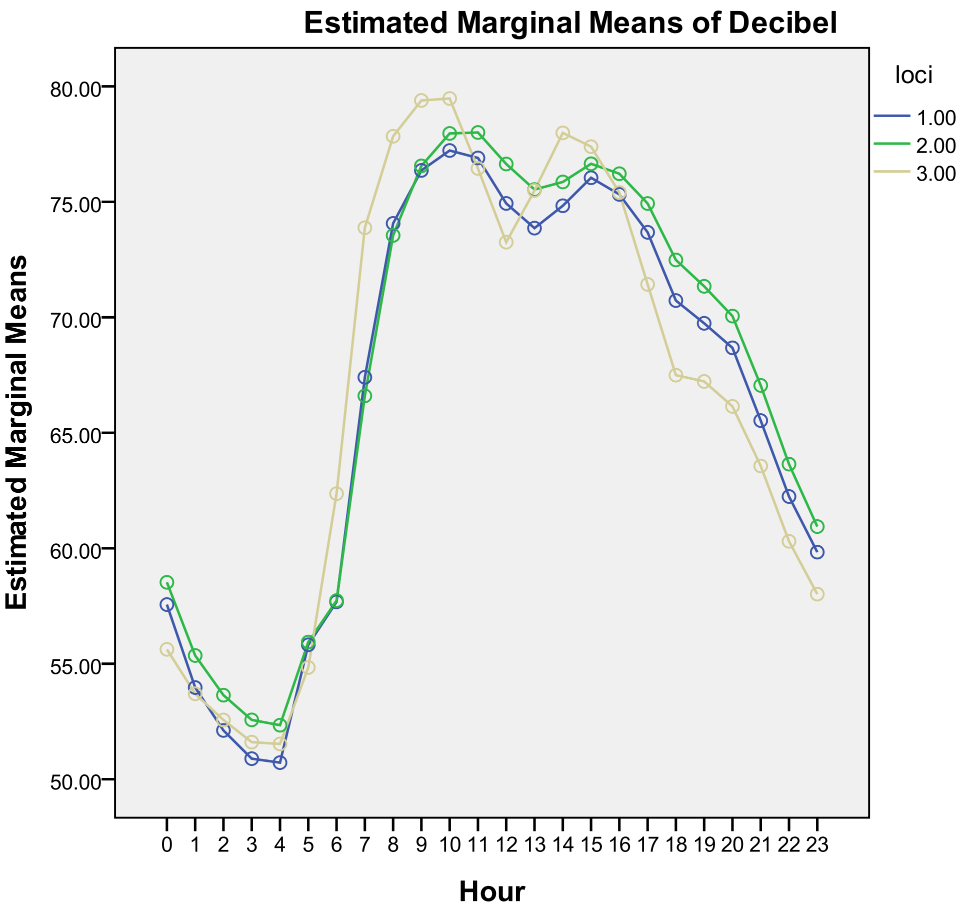

Figure 1. The means of noise per hour on 3 loci (Note：Circles represent the observed values; Each grid on the horizontal axis represents one hour, and each grid on the vertical axis represents 5 dB(A).)

3.4. The curve fitting relationship between population and noise of locus 2

3.4.1. The curve fitting relationship between population and day-shift noise of locus 2

We performed curve fitting for child clients and the noise means on the day shift, based on the cubic model. The specific fitting coefficients of the cubic model are listed in Table 4 and the fitted curves are shown in Figure 2A.

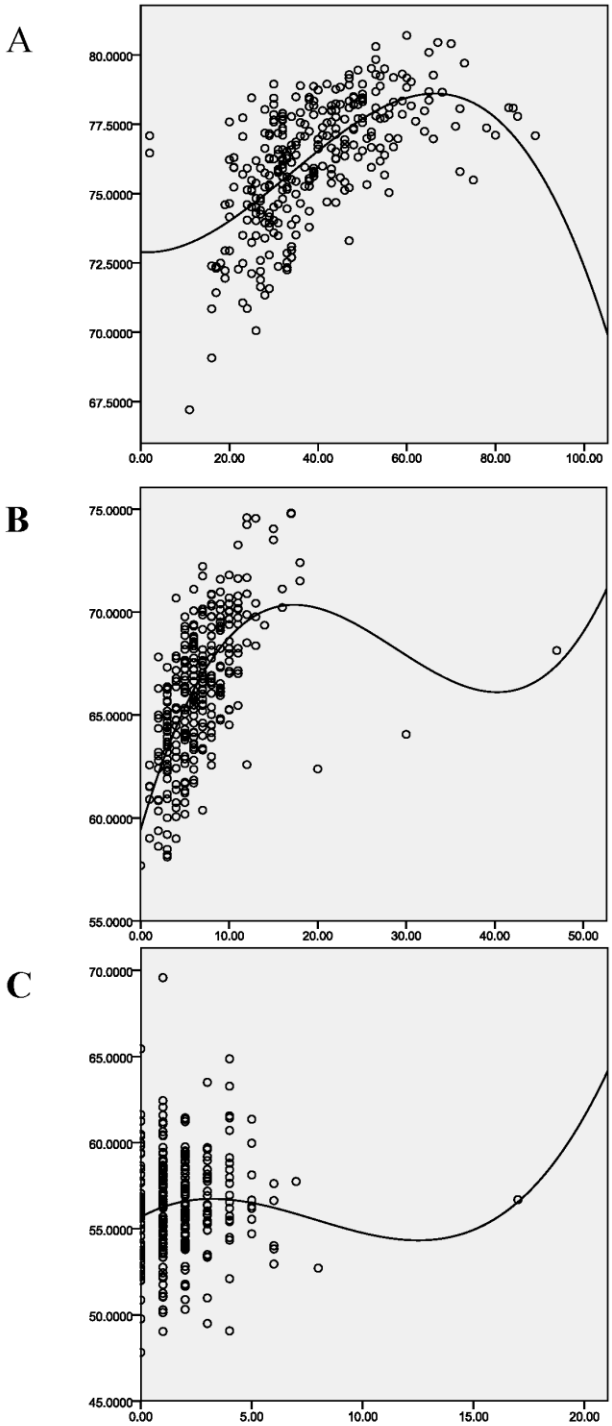

Figure 2. The fitted curve of children clients and the noise means on day (A) and afternoon (B) and night (C) shift (Note：Circles represent the observed values; Each grid on the horizontal axis represents one hour, and each grid on the vertical axis represents 5 dB(A).)

The correlation analysis showed that noise levels were positively associated with the number of patients ($p < 0.001$) (Table 4). We can obtain a cubic model: $Y=72.894-0.013X+0.004X^2+0.000X^3$.

Table 4. Model Summary and Parameter Estimates

Equation	Model Summary					Parameter Estimate			
	r^2	F	df1	df2	p	Constant	b1	b2	b3
Day cubic	0.419	72.040	3	300	<0.001	72.894	-0.013	0.004	0.000
Afternoon cubic	0.453	82.904	3	300	<0.001	59.436	1.470	-0.061	0.001
Night cubic	0.017	1.774	3	300	0.152	55.669	0.725	-0.142	0.006

3.4.2. The curve fitting relationship between population and afternoon-shift noise of locus 2

We performed curve fitting for child clients of the afternoon shift and the noise means of the afternoon shift based on the cubic model. The specific fitting coefficients of the cubic model are listed in Table 4 and the fitted curves are shown in Figure 2B.

Correlation analysis showed that noise levels were positively associated with the number of patients ($p < 0.001$) (Table 4). We can obtain a cubic model: $Y=59.436+1.470X-0.061X^2+0.001X^3$.

3.4.3. The curve fitting relationship between population and night-shift noise of locus 2

We performed curve fitting for child clients of night shifts and the noise means of night shifts based on the cubic model. The specific fitting coefficients of the cubic model are listed in Table 4 and the fitted curves are shown in Figure 2C.

The correlation analysis showed that noise levels were positively associated with the number of patients ($p = 0.152$) (Table 4). The results were not statistically significant ($p > 0.05$). This may be related to the lower number of night-shift patients and weak influence of the number of people on noise.

4. Discussion

Noise is everywhere in hospital. Especially for the pediatric emergency care department, the noise pollution is more noticeable due to the patient's early age. Excessive noise levels have a particularly significant impact on health of nurses and patients. In our study, we have found a positive correlation between the noise value and the number of individuals in the pediatric emergency care room. We also have found a positive correlation between the noise value and the client number. Therefore, it is particularly important to manage noise pollution by understanding ward noise patterns. Nurse could organize visits more appropriately to control the noise level and lessen the impact on health.

4.1. Noise exposure in pediatric emergency care department

The data analysis in this study showed that the average day and night noises in pediatric emergency care department exceeded the standard of Category 1 acoustic environment functional areas. The rate of exceeding the standard was relatively high at every point during day and night. Table 1 showed that the peak stage of the daytime noise was 07:00-17:00, and the average noise value at the peak stage was more than 70 dB (A). This is consistent with research conducted in other countries or regions worldwide [3,19]. In China, zhao et al. [18] reported that the average and highest voice levels of NICU were approximately 50–75 dB and 105 dB, respectively. The EPA strictly limits hospital noise (daytime value < 50.0 dB (A), night value < 35.0 dB (A)), but few hospitals can reduce the sound level to this limit [17,20]. The peak period covers the working hours of the day shift, which is the relatively concentrated stage of emergency care and emergency patient visits and nursing operations, as well as the period with the highest human flow density. Noise pollution in pediatric departments is closely related to younger age and family members accompanying children [21,22]. The study showed that patients younger than ten years old elicited higher ranges of elevated noise [19]. Noise pollution in pediatric departments severely affects the psychological and physiological status of children and staff to varying degrees. The study showed daytime and nighttime environmental noise exposure was significantly associated with the duration of headaches [23].

4.2. Noise characteristics of pediatric emergency care department

The 24-hour measurements of the three loci were analyzed, and the three mean graphs were in good agreement. Noise peaks occurred during the working hours (06:00-12:00, 15:00-18:00). The diurnal trough of noise also occurred during daytime breaks. Therefore, noise fluctuation is closely related to working hours; during the peak period (6:00-10:00), the number of waiting areas at locus 3 was greater than those at loci 1 and 2. At this stage, the noise value of locus 3 was higher than those of loci 1 and 2 ($p < 0.05$). At the end of the visit (after 16:00), the number of loci 3 was lower than those of loci 1 and 2 ($p < 0.05$). The trend of the mean noise at loci 1, 2, and 3 was similar, and the peak time of entering and falling was later than that at locus 3. This phenomenon may be related to the pediatric emergency care and emergency treatment processes. Most patients first consulted a doctor and then visited various departments. At 3:00 PM, some patients returned to the puncture and observation areas for treatment. Therefore, the noise in pediatric emergency care department is related to the direction of crowd flow; in general, the noise of pediatric emergency treatment is mainly related to the population density and fluctuates with the movement of the population.

4.3. Noise Management Scheme

First, improving service quality is to help reduce noise levels. The noise in the daytime department room mainly comes from people's voices, including the crying of children and communication between doctors and patients [12,24]. Efficient medical services can reduce the length of stay [22]. Nurses can further clarify patients' needs and make reasonable arrangements to effectively divert patients who require doctor visits, examinations, treatments, and other services in order to avoid overcrowding. This can reduce the crowd density and noise. Second, we should focus on and control noise peak. During the peak period, an additional person was deployed to maintain the order. When disputes arise, family members should be transferred to an independent space as soon as possible to appeal and avoid crowds. Increasing visits to children and performing prospective treatment for patient needs can efficiently reduce the incidence of adverse events. From the perspective of a service object, we need to optimize the presentation of matters to reduce unnecessary low-quality communications [25,26]. Additionally, staff should be trained to communicate in lower voices and to minimize unnecessary conversations in patient care areas [26]. Furthermore, patient education and engagement can also play a role in noise reduction [8,27]. By informing patients and visitors about the importance of maintaining a quiet environment and providing them with guidelines on how to contribute to noise control, hospitals can foster a culture of quiet and respect that benefits everyone. Finally, improving the hospital environment is particularly important. Functionalizing the department structure and separating different areas may be an efficient approach. In particular, the puncture area should be set up in an independent space to avoid affecting adjacent areas during treatment. The wall material of the department should be optimized and a sound insulation material should be selected [25,28].

4.4 limitations

There are also some limitations in our study. First, we only measured noise levels over a 24-hour period in the pediatric emergency care department. The data collection for noise levels in the pediatric emergency care department may have been influenced by unforeseen variables, such as shifts in staff behavior, which could have impacted the noise levels but were not fully accounted for in the study design. Second, the study was confined to a single pediatric emergency care department, limiting the generalizability of the findings to other similar settings. Third, while the study provides a descriptive analysis of noise levels over time, it may not have explored the potential long-term health impacts of noise exposure on patients and staff, which could be an important area for future study.

5. Conclusion

Noise pollution severely endangers the physical and mental health of clients and staff; however, the present situation of the acoustic environment in pediatric emergency cares and emergency treatment rooms is not optimistic. It is difficult to reduce the noise caused by the crowds. This study aimed to determine the factors that influence noise. The data show that there is a certain relationship between noise and population density and that activity law and noise can be relieved by reducing the population density and improving the treatment process. Additionally, incorporating noise monitoring into hospital policies is crucial for identifying and addressing noise pollution issues. Furthermore, implementing control measures is essential to ensure a quieter and more conducive healing environment for patients and clinical staffs. Determining the effectiveness of some actions and strategies may be further researched to reduce noise in the pediatric system.

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Statements of ethical approval

This study has no ethical implications.

Conflict of Interest

The authors declared no conflict of interest.

Author Contributions

Yuan Luo and Yunchen Li: study design, data collection, data analysis and article revision.

Yuan Luo, Yunchen Li and Liping Zhao: article writing.

Liping Zhao and Yunchen Li: article guide.

Yunchen Li: Funding support.

All authors contributed to the article and approved the submitted version.

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References

[1] Stansfeld SA, Matheson MP. Noise pollution: non-auditory effects on health. *British medical bulletin*. 2003;68:243-57. doi:10.1093/bmb/ldg033

[2] Yarar O, Temizsoy E, Günay O. Noise pollution level in a pediatric hospital. *International Journal of Environmental Science and Technology*. 2019/09/01 2019;16(9):5107-5112. doi:10.1007/s13762-018-1831-7

[3] Kramer B, Joshi P, Heard C. Noise pollution levels in the pediatric intensive care unit. *Journal of critical care*. Dec 2016;36:111-115. doi:10.1016/j.jcrc.2016.06.029

[4] Jadid K, Klein U, Meinke D. Assessment of noise exposures in a pediatric dentistry residency clinic. *Pediatric dentistry*. Jul-Aug 2011;33(4):343-8.

[5] Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environmental health perspectives*. Mar 2000;108 Suppl 1(Suppl 1):123-31. doi:10.1289/ehp.00108s1123

[6] Stansfeld SA, Berglund B, Clark C, et al. Aircraft and road traffic noise and children's cognition and health: a cross-national study. *Lancet (London, England)*. Jun 4-10 2005;365(9475):1942-9. doi:10.1016/S0140-6736(05)66660-3

[7] Santos JA-O, Carvalhais CA-O, Xavier A, Silva MA-OX. Assessment and characterization of sound pressure levels in Portuguese neonatal intensive care units. *Arch Environ Occup Health*. 2018;73(2):121-127. doi:10.1080/19338244.2017.1304883

[8] de Lima Andrade E, da Cunha ESDC, de Lima EA, de Oliveira RA, Zannin PHT, Martins ACG. Environmental noise in hospitals: a systematic review. *Environ Sci Pollut Res Int*. Apr 2021;28(16):19629-19642. doi:10.1007/s11356-021-13211-2

[9] Marsh JP, Jellicoe P Fau - Black B, Black B Fau - Monson RC, Monson Rc Fau - Clark TA, Clark TA. Noise levels in adult and pediatric orthopedic cast clinics. *Am J Orthop (Belle Mead NJ)*. 2011;40(7):E122-124.

[10] Choiniere DB. The effects of hospital noise. *Nurs Adm Q*. Oct-Dec 2010;34(4):327-33. doi:10.1097/NAQ.0b013e3181f563db

[11] Fasih-Ramandi F, Nadri H. Background noise in Iranian hospital intensive care units. Article. *Noise Control Engineering Journal*. 2017;65(1):14-21. doi:10.3397/1/376422

[12] Xyrichis A, Wynne J, Mackrill J, Rafferty AM, Carlyle A. Noise pollution in hospitals. *BMJ (Clinical research ed)*. Nov 18 2018;363:k4808. doi:10.1136/bmj.k4808

[13] United States, Office of Noise Abatement. *Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety*. in for sale by the Supt. of Docs, US Govt. Print. Off, 74.4; 1974.

[14] American Academy of Pediatrics Committee on Environmental Health. Noise: a hazard for the fetus and newborn. *Pediatrics*. Oct 1997;100(4):724-7.

[15] Berglund B. Guidelines for community noise. *World Health Organization*. 1999;

[16] People's Republic of China. Environmental quality standards for noise. https://std.samr.gov.cn/gb/search/gbDetailed?id=71F772D8219DD3A7E05397BE0A0AB82A.

[17] People's Republic of China. Technical specifications for environmental noise monitoring, Urban sound environment routine monitoring. https://std.samr.gov.cn/hb/search/stdHBDetailed?id=A314A3F9CA9753AFE05397BE0A0A8C2E.

[18] Zhao Lijin, Zhao Minhui. The effect of noise on premature infants and the research progress of noise reduction measures. *China Maternal and Child Health Res*. 2017;28(4):481-483. doi:10.3969/j.issn.1673-5293.2017.04.040

[19] Ahmad JG, Allen DZ, Erickson S, et al. Noise exposure in pediatric otolaryngology clinic: A sound survey of a single-institution tertiary care facility. *Am J Otolaryngol*. Jul-Aug 2023;44(4):103913. doi:10.1016/j.amjoto.2023.103913

[20] Silverstein M. Getting Home Safe and Sound: Occupational Safety and Health Administration at 38. *American Journal of Public Health*. 2008;98(3):416-423. doi:10.2105/ajph.2007.117382

[21] McGough NNH, Keane T, Uppal A, et al. Noise Reduction in Progressive Care Units. *Journal of nursing care quality*. Apr/Jun 2018;33(2):166-172. doi:10.1097/ncq.0000000000000275

[22] Soubra M, Harb YA, Hatoum S, et al. Effect of a Quality Improvement Project to Reduce Noise in a Pediatric Unit. *MCN The American journal of maternal child nursing*. Mar/Apr 2018;43(2):83-88. doi:10.1097/nmc.0000000000000413

[23] Lee S, Kim KR, Lee W. Exploring the link between pediatric headaches and environmental noise exposure. *BMC Pediatr*. Feb 2 2024;24(1):94. doi:10.1186/s12887-023-04490-4

[24] Zamani K, Asgharnia H, Yazdani J, Taraghi Z. *The effect of staff training on the amount of sound pollution in the intensive care unit*. vol 5. 2018:130-133.

[25] Busch-Vishniac I. Hospital Soundscapes: Characterization, Impacts, and Interventions. *Acoustics Today*. 2019;15(3)doi:10.1121/at.2019.15.3.11

[26] Zijlstra E, Hagedoorn M, Krijnen WP, van der Schans CP, Mobach MP. The effect of a non-talking rule on the sound level and perception of patients in an outpatient infusion center. *PLoS One*. 2019;14(2):e0212804. doi:10.1371/journal.pone.0212804

[27] Astin F, Stephenson J, Wakefield J, et al. Night-time Noise Levels and Patients' Sleep Experiences in a Medical Assessment Unit in Northern England. *The Open Nursing Journal*. 2020;14(1):80-91. doi:10.2174/1874434602014010080

[28] Chen C-Y. Characterizing Subjective Noisiness in Hospital Lobbies. *Archives of Acoustics*. 2015;40(2):235-246. doi:10.1515/aoa-2015-0026