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Hearing Loss in Schoolchildren Attending a School Close to a Source of Urban Noise Pollution

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Abstract: *Background:* Noise induced hearing loss is a sensory impairment prevalent at any age. It is a risk factor for school performance decline in countries in low-incomes countries. In this study, we find very few studies on this scientific evidence in sub-Saharan countries. *Objective:* to assess the association between hearing loss and performance in young schoolchildren, and whether exposure to environmental noise has moderated this association among young primary school children in an educational district in Kinshasa. Methods: A cross-sectional descriptive study on data obtained from a representative urban survey between 2019 and 2021. A total of 158 children aged 11 to 16 eligible for TENAFEP and with a dichotomized measure of auditory status found or not during an ENT examination were included. Cognition was measured using SIFTER and TENAFEP results. *Results:* Noise and hearing impairment in this study were associated with decreased academic performance, with an odds ratio of 2.48 (1.22-5.06). By comparing the 2 sub-sets we find that the prevalence of risk is 8% higher in schoolchildren with hearing impairment compared to normal-hearing students. Attendance at the places of worship and discos moderated the association between hearing loss and auditory perception reflected in school performance for all samples and the boys' sample. *Conclusion:* Noise was associated with deafness and academic performance, and music of discos and worship moderated association in boys rather than girls.

Keywords: Hearing Impairment, Environmental Noise, Schoolchildren Performance

1. Introduction

School performance reflects the intellectual coefficient and also derives from the sound environmental conditions in homes and on school facades. Noise pollution is a contributing factor to deafness. Hearing loss is very common in schools, with a prevalence of 6% worldwide [1, 2]. The causes of deafness in children can be hereditary, congenital or acquired of infectious, traumatic origin. Drug ototoxicity has developed as a corollary to the explosion of the pharmacological industry. Acute and/or chronic sound trauma is now recognized as a source of hidden [3] or symptomatic deafness.

Environmental noise in urban areas has developed at the expense of urbanization and exponential industrialization at the global level over the last 5 decades. The sites intended for schools, once located outside the hubbubs due to road traffic and leisure music, are now bathed and on a large scale, in this adjoining discomfort.

Several previous studies have shown that the sound environment in school environments is at the origin of certain sensorineural deafness [4, 5]. Since 2012, researchers at the

Kresge Hearing Research Institute (Michigan) and the team of Charles Liberman (United States of America), have shown that the decrease in speech intelligibility in a noisy environment is due, among other things, to hidden deafness [6].

To date, very few studies have included these cases in the prevalence of deafness in schools. Indeed, in a classic way, the audiogram of the auditory thresholds by the pure tone audiometry (PTA) do not detect this type of deafness [7]. The expology of this problem has already been documented in the high-income country. In the Democratic Republic of Congo there is no systematic screening program for deafness in schools to assess this phenomenon in a young population.

This study aimed to assess the association between hearing loss and performance in young students, and whether exposure to environmental noise moderated this association among young primary school children in an educational district in Kinshasa.

It also proposes to look for cases of hearing loss and determine their correlation with the decline in school performance in a school close to a source of noise pollution and located in one of the communes of the city of Kinshasa.

2. Methods

This is a cross-sectional and comparative study that crosses the period from September 2019 to December 2021 stigmatized by the COVID-19 pandemic. This study took place in a primary school within the Saint Pierre school complex in the commune of Kinshasa whose sound source was identified, quantified and qualified after characterization.

This school was randomly selected from those with exposure levels above 35 dB A, considered as the maximum average exposure level in a school environment [8]. In a survey on the level of ambient noise in Lukunga district an average of 45 dBA was found.

All students enrolled in the sixth grade and eligible for the Primary School Leaving Examination Test (TENAFEP) were selected from our sample.

2.1. Hearing Measures

2.1.1. Pure Tone Audiometry

In our study, hearing was assessed using a PTA measure according American Speech-Language-Hearing Association (ASHA) Committee on Audiometric Evaluation (20060605). Ear-specific hearing thresholds without a hearing aid were measured from 500 to 8000 Hz. Higher decibel thresholds indicated poorer hearing. The basic exploration concerned deafness, as defined by the hearing threshold on 4 frequencies in the best ear, representing the average threshold at 500, 1000, 2000 and 4000 Hz. The choice of the best average ear hearing threshold was consistent with previous epidemiological studies [9, 10] of age-related deafness. The threshold on the frequency 8000 Hz was evaluated to explore hidden deafness.

Hearing loss was defined by the clinical and research threshold used worldwide of an PTA greater than 25 dB HL. Traditionally, normal hearing is defined as an average hearing threshold of 25 dB HL or less. In a sensitivity analysis, we defined miming deafness as an auditory threshold greater than 15 dB HL. In this study, we defined subclinical deafness as an auditory threshold of 1 to 25 dB HL.

2.1.2. Digit Triplet Test (DTT)

The procedure below corresponds to the telephone version of the DTT.

This is an adaptive procedure where the noise is fixed.

We begin the presentation of the number at -8 dB NSR with a sequence of three digits (between 1 to 9) chosen randomly. The listener must then indicate his 3 answers via a numeric keypad and the triplet is considered correct when all the numbers are well rendered. The speech level is adjusted in steps of -2 dB NSR if the triplet is correct and +2 dB NSR if the triplet is false. A total of 27 triplets are presented in each test.

The result was given by the average of the NSR of the last 22 iterations (including the NSR adjusted after the 27^{th} presentation).

2.2. Noise Measurement

For noise measurement, via a sound level meter that will be connected to a computer that will collect the information via a Trotec 400 software that will store it and this data will be exported to a database.

2.3. Data Collection

Data on the pupil's address, age and noise information around the school and residence of those students who have lived at least two years at that address found on the day of collection or study.

The data collected will concern:

1) Environmental noise around the school and around the home where the respondent lives (Student), which represent the sound level in dB A as a numerical variable for one hour and then classified according to source and type, as a qualitative variable; this variable will express the intensity of noise taken by means of a sound level meter.
2) School performance at the national primary school leaving test (TENAFEP), collected as a percentage as a numerical variable, can be transformed into a qualitative variable by grouping the percentage according to success or failure.
3) The psychological state of the student, collected as a qualitative variable. Via the Verbal Comprehension Index. Subtests: (similarity, vocabulary and comprehension).
4) Cognitive ability thanks to TENAFEP results and S.I.F.T.E.R score.
5) The examination of the auditory state will be done through an ENT examination (PTA and DTT).
6) Information on environmental noise will be collected by 5 doctors, at school and in the 70 households, during 17 days of visit to the homes where the students reside for sonometry in the residential environments.

2.4. Data Processing

Data processing will include data sorting, quality control and actual processing.

The first quality control will be carried out in the field by investigators, doctors and public health experts who will check whether the inclusion and non-inclusion criteria are met and whether the answers are complete and correctly scored. During collection, the data sent will be evaluated as soon as it is received by the supervisors.

The actual data processing will consist of dividing the data into different categories and their codification. For closed-ended questions, categories will be created in the questionnaires. They will relate to the possible options. On the other hand, for open-ended questions the categories will be created after data collection.

2.4.1. Quantitative Data Will Be Collected Via

1) *For noise measurement,* via a sound level meter that will be connected to a computer that will collect the information via a Trotec 400 software that will store it and this data will be exported to a database.

Sound Pressure Level according to Jack Hammers

a) *Scale dB*

b) $L_{max:}$ the highest sound pressure level in a given period.

c) $L_{eq:}$ Average sound pressure level within a certain period of time. If filter A is used for frequency weighting, the average level is called L_{Aeq}. The filter and time period used for the mean are often indicated as an index, for example, L_{Aeq8h}, $L_{Aeq23–7h}$, or L_{night}.

d) $L_{DEN:}$ L_{DEN} (Level-Day-Evening-Night), *For the cognitive ability* of the student using the results of TENAFEP and the standardized screening instrument for targeting educational risk (S.I.F.T.E.R.) questionnaire that will be addressed to the teacher of the selected student, which will give us qualitative data that will be coded.

2) *For the data on the hearing* of the pupils, they will be collected during an ENT exam, then encoded in a database for statistical processing with the IBM SPSS version 26.0.

2.4.2. Processing of Qualitative Data

Qualitative data will be collected during interviews with the various pupil leaders (parents and teachers). The doctors who will be trained for the collection tool will be used to process the data and centralize explanations on the subject using a grid as a guide.

A quality control of the completion of the questionnaires will be carried out by the coordination team composed of the principal investigator and the secondary investigators. Next to each quiz will be attached the related observation note, in order to take it into account.

2.5. Data Analysis

The data collected was entered, encoded and managed using MS Office Excel 2016 by the researcher.

A multivariate logistic regression model to calculate odd ratios for associations between hearing loss and various factors. The model included demographic characteristics; known risk factors; and associations between hearing loss and noise sources.

Structural equation modelling made it possible to analyze the relationships between latent variables: noise, hearing loss and school performance.

All statistical analyzes were performed using IBM SPSS version 26.0 with the possibility of exporting to dedicated software for structural modeling. Statistical significance was defined as a double-sided p-value < 0.05.

3. Results

Table 1 presents the results of all students i.e., 238 students in the 6^{th} grade in elementary school EP V ST Peter, eligible for the TENAFEP test, concerning their hearing: 16% (DTT, 31.1%; PTA: 12.4%) with hearing loss, their average age 12.76 SD 2.81 years.

Table 1. *Main characteristics of the study population by socio-economic, auditory and gender status.*

CHARACTERISTICS	score	Hearing screening		p
		HEARING IMPAIRMNMENT N (%)	NORMAL HEARING N (%)	
Father-reported	HL	25 (12.5)	175 (87.5)	0.002
	normal	13 (34.2)	25 (65.8)	
EXAMINATION Type	DTT	14 (31.1)	31 (68.9)	0.004
	PTA	24 (12.4)	169 (87.6)	
Tubal dysfunction	Bilateral	5 (45.5)	6 (54.5)	0.006
	Right ear	5 (21.7)	18 (78.3)	
	Left ear	4 (33.3)	8 (66.7)	
	normal	24 (12.5)	168 (87.5)	
Residential environment	Poor environment	22 (16.7)	110 (83.3)	0.859
	Rich environment	16 (15.1)	90 (84.9)	
Gender	Male	18 (16.2)	93 (83.8)	0.922
	Female	20 (15.7)	107 (84.3)	
Age range (years)	Child (11-13)	32 (19.6)	131 (80.4)	0.035
	Teenager (14-16)	6 (8)	69 (92)	
Otoscopy	Amended	13 (30.6)	43 (69.4)	0.0004
	Normal	19 (10.8)	157 (89.2)	

CHARACTERISTICS	score	Hearing screening		p
		HEARING IMPAIRMNMENT N (%)	NORMAL HEARING N (%)	
Type of deafness	Hidden	2 (9.5)	19 (90.5)	0.129
	Moderate	7 (31.8)	15 (68.2)	
	Minimal	9 (11.4)	70 (88.6)	
	Light	20 (17.2)	96 (82.8)	
Socio-economic status (SES)	Classes 1-2-3	14 (11.8)	105 (88.2)	0.142
	Classes 4-5	10 (20.8)	38 (79.2)	

3.1. School Performance

Table 1 highlights the performance of students according to their residential environments. Students in rich urban areas perform better than those in poor backgrounds, and the difference is significant at the 5% threshold.

In rich urban areas (SES 1.2) more than 50% of students have more than 60%, unlike in poor areas where half have less. Indeed, in the rich urban environment, the infrastructures and equipment, less noisy and allowing to learn better are located there (electricity, library, internet, transport...).

However, in poor, noisy environments, students are sometimes very far from school, and are exposed to noise pollution, all these factors contribute to poor school performance.

3.2. Noise Level

At the level of the facades of schools and homes.

By describing during a single visit to the schools concerned by this study, we found that noise from bars, churches and road traffic was the main source of noise pollution, with the exception of the rear facades, where we found that the main sources of noise were the music of religious places of worship, discos, generators and bars located nearby.

Most respondents reported being exposed to noise in homes, especially students living in poor neighborhoods (88%).

The proportions of participants who reported being affected by noise in other spaces or circumstances (recreation, games) were 76% and 64%, respectively.

Environmental noise level measured in schools.

Table 2 and Figure 1 display and analyze the ratio of noise levels recorded at different coordinates in the courtyards of the schools under scrutiny. Average noise levels recorded in school yards ranged from 68.3 dB A (L eq day) to 84.7 dB A outdoors on playgrounds and between 69.5 dB A and 76.1 dB A inside classrooms. These ranges of values were above the WHO recommended noise level of 35 dB A for school facades learning environments. In one of the classrooms the highest average noise level was recorded, 86.1 dB A for noise within the classrooms; the average measurement in this school was 84.7 dB A for outdoor playground noise. On the other hand, the lowest average noise level recorded was 68.3 dB A for class (indoor) noise; the average measurement in this school was 74.4 dB A for indoor playground noise. The noise levels measured came from the external sources reported and identified, and that derived from the street vendors.

The structural equation modelling (Figure 1) is based on the measurement model represented by 10 manifest variables or items and 3 latent variables including 2 independent, noise and hearing, and 1 dependent variable, school performance. The different correlation coefficients calculated expressed relationships between these variables. The effect sizes rendered by parameter d suggest that these effects are weakly high, overall.

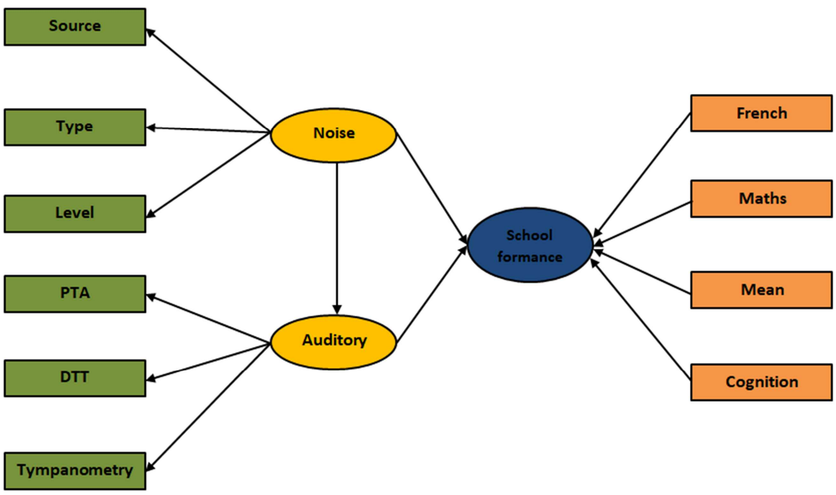

Figure 1. *Modeling by structural equations with latent variables: noise, hearing and school performance, according to a contextualized scale.*

Legends:
Beta 1 (noise-→School Performance): r− 0.108; d: 0.82;
Beta 2 (noise-→Audition): r− 0.103; d: 0.81;
Beta 3 (hearing→SP): r− 0.106; d: 0.94.

Table 2. *Sources and intensity of environmental noise.*

School	Sound level	Home
Street vendor	55dBA	Refrigerator
Conversation in an office	60dBA	Dishwasher
Canteen / Restaurant / Alarm clock 70dBA	70dBA	Canteen / Restaurant / Alarm clock
Office Set/	75dBA	Vacuum cleaner
Hand saw	85dBA	Motorcycle
Machine shop	87 dB A	Circular saw/Gas mower
Ambulance/screwdriver	95dBA	Pneumatic screwdriver/ electric generator/ MP3 player/religious worship
Accelerating a truck, generator	110dBA	generator
Hammer Blow/ Game Stadium	110dBA	Stadium of games
Train whistle/	120 dB	Outdoor Concert /Rock/Gospel Campaign
Jackhammer/	130dBA	Car racing
Dynamite/	140dBA	Bicycle horn
Tire puncture	150dBA	
Rubble quarry / Firecracker	160dBA-170 dB A	Rifle shot

Although the associations were significant, the different sizes of the noise effect, regarding the decrease in hearing ability compared to the results in French are all very small. The size of the effect on the TENAFEP mean was slightly higher, but still low. Students with known hearing loss performed worse in mathematics. A chi square independence test indicated a significant association between the category of students with multiple problems (noise) and auditory status in relation to those with normal hearing (p <0.001). Analyzing d Cohen effect, we found a mild association between noise and hearing ability compared to those with known cognitive decline (TENAFEP), more strongly associated with higher "deafness".

4. Discussion

According to the literature consulted on codification, PTA is the first crucial moment in an investigation of auditory function. In the present study a dedicated tool was used to assess the hearing threshold of students using the DTT in order to better assess hearing in noise and in strict compliance with barrier measures against COVD 19. Prendergast finds that DTT has an 80% sensitivity and a specificity of 92% compared to PTA. 60% of children were assessed using this tool.

Schoolchildren with hearing loss and in a hostile sound environment face an excessive set of challenges related to multiple disabilities, including cognitive disability. The association between noise pollution and hearing loss even at mild levels shows cognitive interference on school performance outcomes; of speech and language difficulties, academic results and behavior, in order of importance (according to the results as reported by SIFTER) [11-16]. Where cognitive impairment and hearing loss or hearing loss and environmental noise were associated, the result was more cumulative than simply "additive" [17], more disabilities reducing the compensation capacity, as indicated in this study [18, 19].

However in the general schoolchildren population exposed to environmental noise, the prevalence of hearing impairment is about 0.05% according to some authors [20] and 2% to 17% (up to 6% - 8%) in this study and other researchers [12, 14]. Boosting our understanding of the presumed unresolved effect of reduced school performance and hearing loss for children in noisy environments due primarily to music, is an important first step towards identifying strategies and services that can help students with known hearing loss maximize their academic performance and cognitive performance (language communication, in attention and academic results).

The WHO estimates that about 45,000 disability-adjusted life years are lost each year in high-income Western European countries for children aged 7 to 19 due to their exposure to ambient noise (29). Mechanisms thought to explain the effects of noise on children's cognition include communication difficulties, impaired attention, increased excitement, incompetence to learn, frustration, noise discomfort, and the performance consequences of sleep disturbances [21, 22].

Previous studies have also suggested stress-related psychological responses as a mechanism because 11-year-olds are less equipped in assessing stressors and have less well-developed coping strategies than 16-year-olds [21].

This mechanism may explain the phenomenon observed in this study where the age group of 11 years was found to be more affected in terms of hearing. We also found that areas with high environmental noise levels are socially disadvantaged, and children in socially severely deprived areas scored worse on cognition and TENAFEP tests than children in SES categories 1 and 2. Therefore, we include measures to assess the socio-economic situation of parents to assess the associations between school performance and urban environmental noise exposure (Sophie Pujol).

As in the present study, several studies have also shown that exposure to ambient noise from road traffic, or places of worship or bars at school and at home has a negative effect on children's school performance and so they perform worse on the national standardized TENAFEP tests than children who are not exposed to noise at school [23].

Many studies have examined the exposure-effect links between noise exposure and cognition to identify the level of exposure at which the deleterious effects of noise begin [24, 25].

The RANCH study of children aged 9 to 10 years attending 89 schools located around ambient noise sources showed a linear exposure-effect relationship between noise exposure at a level of 67 dB A at school and a child's reading comprehension and recognition memory after adjusting for a range of socio-economic factors [25, 26].

This average is very close to the one we found around homes. The favorable period for language acquisition in children is up to the age of 5 years and exposure to noise delays this development in the proportions of 2 months especially concerning the reading ability when the sound level increases by 5 dB A. These linear associations suggest that there is no threshold for effects and that any reduction in noise levels at school should improve cognition, reduce stress and reduce the prevalence of hearing impairment in children.

The ILO guidelines supplemented by the WHO recommendations are strict and peremptory: the noise level in front of schools must remain below 35 dB A during school hours. It has also been recognized that the prevention of hearing impairments and the sanitation of sound space in urban areas by eliminating the sources of noise pollution, in particular bars and certain places of worship, remains the only alternative to improve cognitive processes and school performance [27-29].

However, the most negatively impactful effect is related to the auditory system. This is the best documented effect. Noise was found to have a negative impact on hearing and its deleterious effects were confirmed in this study. In a multivariate correlation the association between noise and hearing loss and school performance was verified and the coefficient r (-3.06) confirmed the moderating role of noise in this mechanism. Noise is the leading preventable cause of hearing loss. Noise-induced hearing loss can be caused by single exposure to intense pulse sound (such as gunshots), or by long-term steady-state exposure with sound pressure levels above L_{UN} 75–85 dB according to old references.

The new references have completely shaken up our way of seeing things. The pathological feature of noise-induced hearing loss is the loss of sensory hearing cells in the cochlea. Currently the notion of auditory synaptopathy has revolutionized our understanding of the pathophysiological mechanism of noise on the auditory system. The lower noise level and over a relatively short period of time can negatively impact hearing, the level of environmental noise that we found in the space of our study is globally between the thresholds of 39- and 78-dB A.

This sound level is likely to cause deleterious effects on the auditory system. The degeneration of the cochlear hair cells being permanent, the sanitation of the sound space and the prevention of hearing impairment can be the only possible options.

5. Conclusions

Overall, 50% of hearing problems are due to noise (1, 29). However, recent research suggests that low noise levels are causes of deleterious effects as harmful as loud noise, but these effects can be sneaky and insidious.

In this study, hearing thresholds appeared to be high and was not related to age. That is why we suggest an improvement of the prevention of hearing loss, to reduce the environmental noise, to carry out a prospective study, particularly in younger children where immaturity of the auditory system can contribute to poorer academic performance.

Conflicts Interest

All the authors do not have any possible conflicts of interest.

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