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Noise Exposure Levels of Priests and Worshippers in Protestant Churches

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Context. *Worship in Protestant churches in Brazil is very noisy. Thus, this practice may pose a hearing risk.* ***Aims***. *To evaluate the priests' and worshippers' noise exposure during worship.* ***Settings and design***. *The analysis was carried out in 5 churches located in the city of São José dos Campos, Brazil.* ***Methods and material***. *To estimate the worshippers' noise exposure, an author of this study was also submitted to dosimetry. The methodology was based on Fundacentro's Occupational Hygiene Standard No. NHO-01 (2001). Weekly noise exposure was estimated according to the priest's information about the number of services in the period.* ***Results***. *The priest's noise exposure was over the recommended limits. The normalized exposure level varied between 95.4 to 99.5 dB(*A*). In 2 of the churches, the noise exposure registered, with values of 85.3 and 86.5 dB(*A*), may also pose risk to the worshippers.* ***Conclusions***. *Worship in the churches generated sound pressure levels that imply health risk, especially to priests, so hearing conservation programs with adequate acoustical sanitation measures must be implemented there.*

noise exposure churches worship

1. INTRODUCTION

In Brazil, there are many studies dedicated to the analysis of noise exposure in several circumstances [1, 2, 3, 4, 5, 6, 7, 8, 9]. In relation to churches, Alves observed that 98% of them in Goiânia generated noise levels above the legislation on municipal urban noise [10]. The use of loudspeakers systems in Indian churches during worship is one of the main causes of disturbance within the population of the state of Delhi, according to Singh and Davar [11].

Considering those studies, it can be supposed there are high noise levels inside other churches, too. None of those articles studied both church workers' and the public's exposure to noise during services in churches.

2. SUBJECTS AND METHODS

Two dosimeters (Larson Davis, USA, model 705A) were used to evaluate noise exposure. The dosimeters were used by the priests during worship.

Five churches in the city of São José dos Campos, Brazil, were selected as the sample. Exposure of one priest per church was analysed. An author of this study was equipped with a dosimeter to act as a worshipper would during the evaluation. He attended five services, one in each church, using the dosimeter with the authorization of the church's responsible.

The set-up of the personal dosimeters was established according to Standard No. NHO-01 that defines a criterion level of 85 dB(*A*) for 8-h exposure with an exchange rate of 3 dB [12]. Before each measurement, the meters were calibrated with a Larson Davis (USA) calibrator (94 dB, 1000 Hz).

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The information about the number of services in the churches either per day or per week was collected through interviews with the priests. With these data it was possible to estimate both the daily and weekly noise exposure according to Standard No. NHO-01 [12].

The data collected in the field were downloaded through special software compatible with the meter. The following values were registered: noise dose (%), daily noise exposure level ($L_{EX,8h}$) and weekly noise exposure level ($L_{EX,w}$). Equation 1 was used to calculate the daily noise dose (D) [12]:

$$D = \left(\frac{T}{T_P} \right) \times 100 \qquad (\%), \qquad (1)$$

where T—daily total time of worker's noise exposure (h), T_P—maximal time allowed at this level (h).

Noise exposure during the whole worship time was measured with a dosimeter (Larson Davis, USA, model 705A). The microphone of the instrument, located in the middle of the shoulder most exposed and oriented approximately parallel to the plane of this shoulder, was tied to both the priest and the worshippers.

The priests' noise exposure varies both during the day and during the week. Thus, the daily noise exposure level ($L_{EX,8h}$), associated with 8-h work time, was calculated as well as the weekly noise exposure ($L_{EX,w}$), according to Standard No. NHO-01 [12].

The main exposure values, equivalent A-weighted sound pressure level (L_{Aeq}) and dose (D) applied to the assessment procedure, are expressed with Equations 2–3:

$$L_{Aeq} = 10 \times \log \left(\frac{480}{T_e} \times \frac{D}{100} \right) + 85 \qquad (\text{dB}(A)), \qquad (2)$$

$$D = \frac{T_e}{480} \times 100 \times 2^{\left(\frac{L_{Aeq} - 85}{3} \right)} \qquad (\%), \qquad (3)$$

in which L_{Aeq}—equivalent A-weighted sound pressure level (dB(A)), D—daily noise dose (%), T_e—exposure time (min).

The level of daily noise exposure ($L_{EX,8h}$), expressed with Equation 4, was determined to compare the occupational exposure limit which corresponds to an 8-h workday.

$$L_{EX,8h} = L_{Aeq} + 10 \log \frac{T_e}{480} \qquad (\text{dB}(A)), \quad (4)$$

where L_{Aeq}—equivalent A-weighted sound pressure level (dB(A)), T_e—exposure time (min).

Standard No. NHO-01 [12] establishes Equation 5 for calculating the level of weekly noise exposure considering the fluctuation of noise in an activity:

$$L_{EX,w} = 10 \times \log \left[\frac{1}{5} \sum_{k=1}^{m} 10^{0.1 \left(L_{EX,8h} \right) k} \right] \text{ (dB}(A)), \quad (5)$$

in which $L_{EX,w}$ —weekly noise exposure level, $L_{EX,8h}$—daily noise exposure level, k—index corresponding to day of week.

Data were collected in accordance with Standard No. NHO-01 [12]. The meter microphone, when possible, was positioned midpoint on the church worker's shoulder that was more exposed. The position of the meter is important during the measurement procedure because of sound variations distributed along the body (Kuhn and Guernsey, as cited by NIOSH [13]).

The registered and calculated noise exposure values were compared with the recommended limits defined by Standard No. NHO-01 [12].

This study was submitted to Itajubá's Medicine School's Ethical Committee for approval.

3. RESULTS

3.1. Observed Churches

Noise was assessed in five Protestant churches. Differing in construction characteristics, the churches could accommodate, from A to E, 100, 250, 400, 550 and 1500 worshippers per service, respectively (Figures 1–5). All the churches were located in a residential zone; the services took place both in the morning and in the evening.

Assuming that 550 people can be accommodated in a space of 100 m^2 and a height of ~5 m, the capacity of the churches can be calculated as, from A to E, 1444, 263, 1050, 656 and 3938 m^3, respectively.

Worship concentrates at weekends. Normally there are four services in this period. In these services, songs played through an amplifier are a common characteristic. Musical instruments like guitars, drums, basses and pianos are played, too.

Figure 1. Internal view of church A.

Figure 2. Internal view of church B.

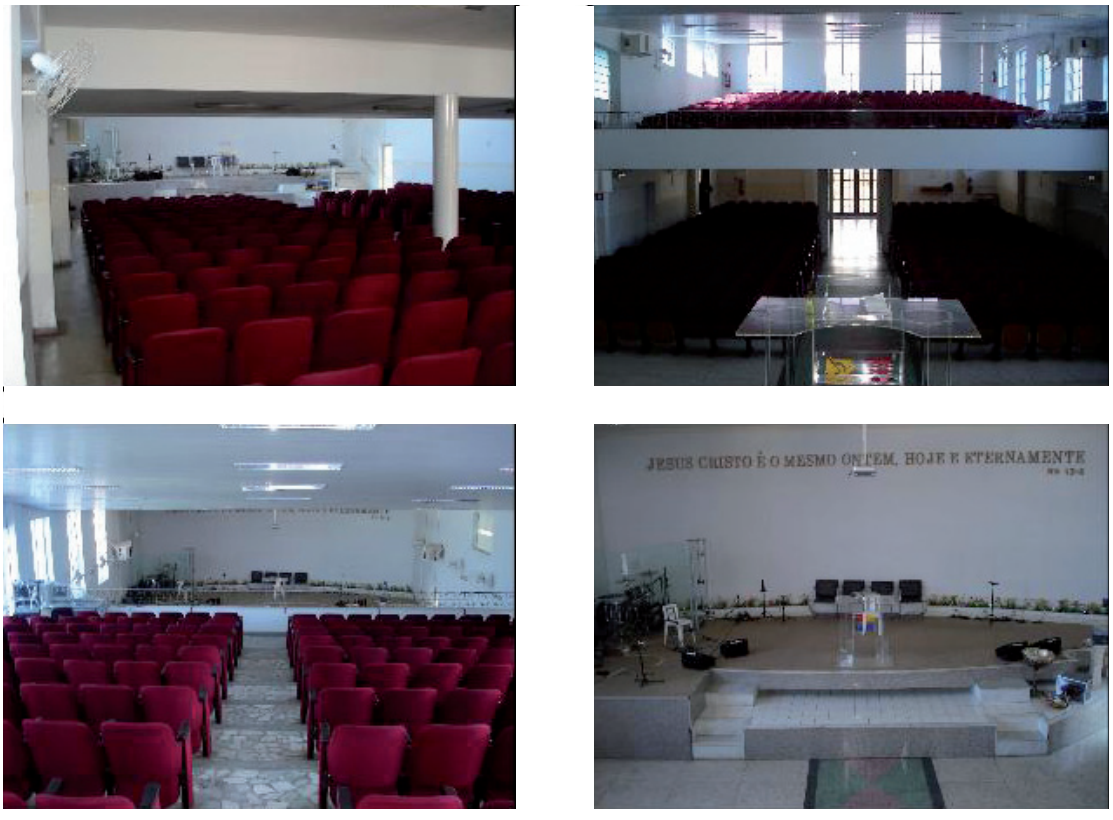

Figure 3. Internal view of church C.

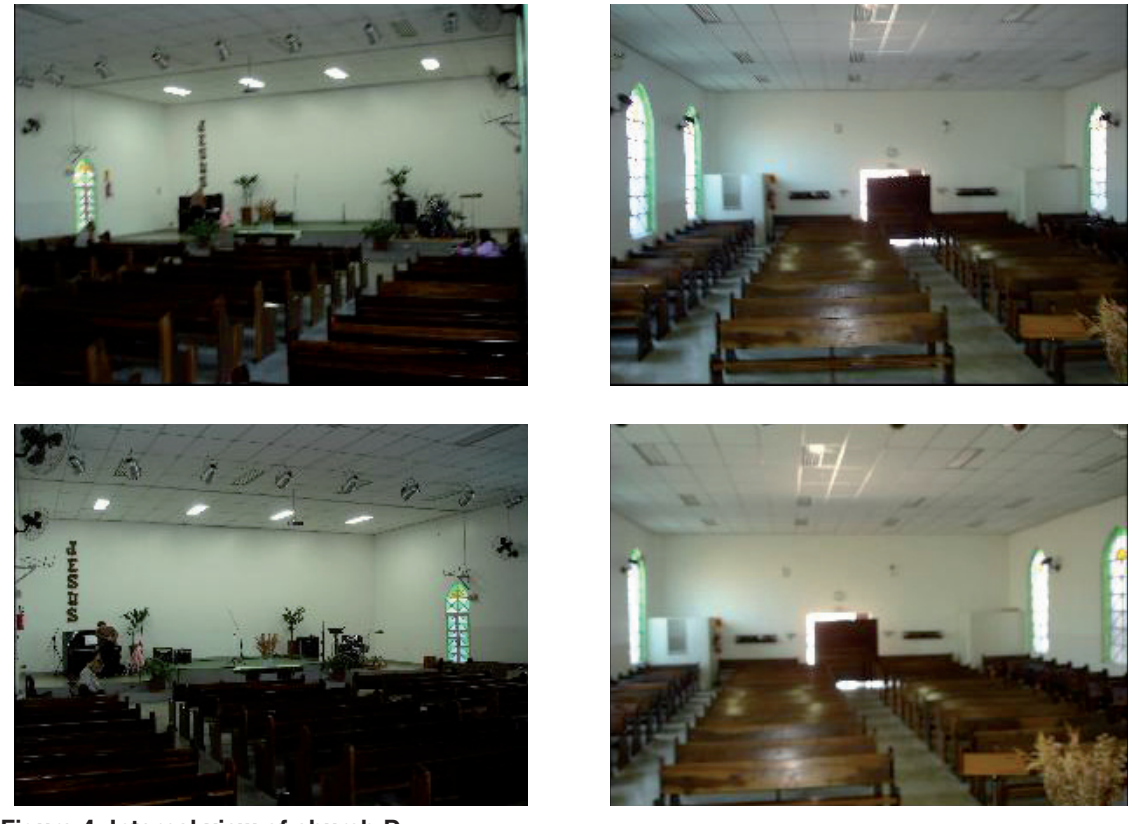

Figure 4. Internal view of church D.

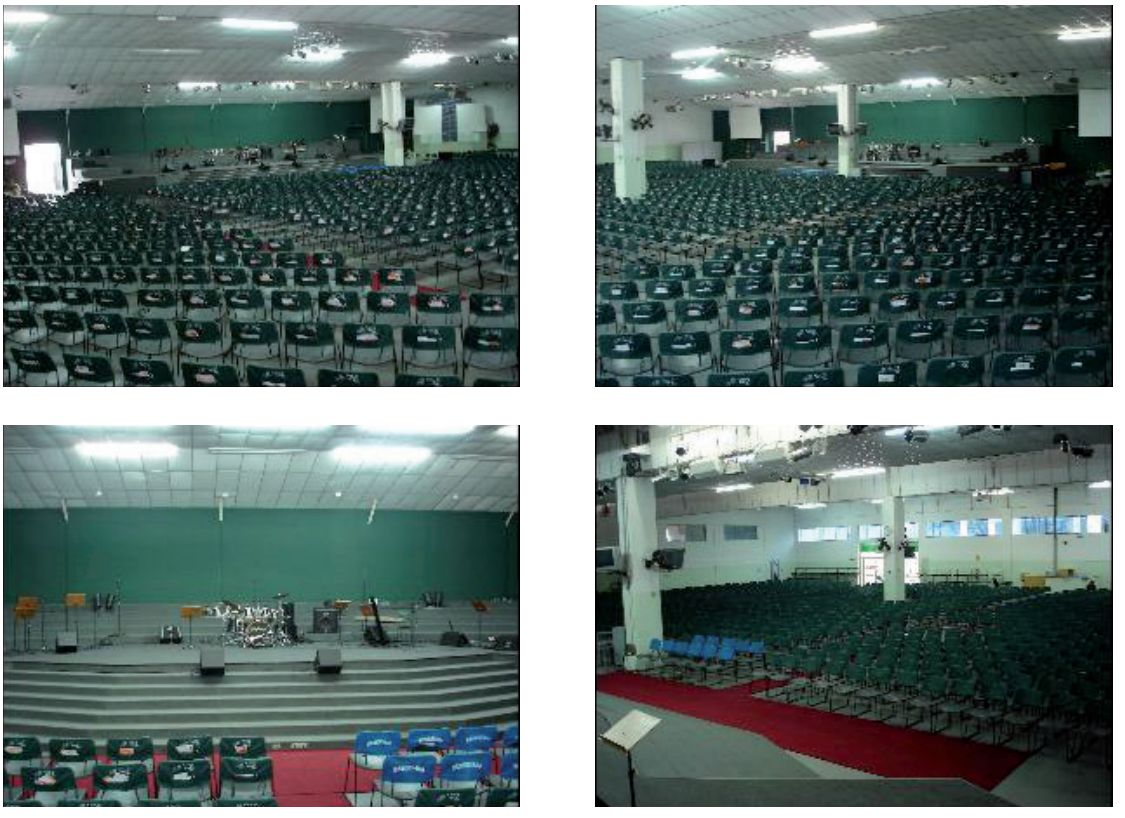

Figure 5. Internal view of church E.

3.2. Dosimetry

Tables 1–2 show the results of the dosimetries carried out in the five churches on priests and the general public.

The $L_{EX,8h}$ values in Table 1 indicated that in all churches there was excessive noise exposure once the values were above the recommended level of 85 dB(*A*) for 8-h exposure. There were no important differences between the $L_{EX,8h}$ values: 95.4–99.5 dB(*A*) in churches A–E. In church E, the one with greatest capacity, the exposure value is very relevant since the projected dose for an 8-h period would be 11 143%, with 100% being the dose limit.

In relation to the worshippers' noise exposure scenario, it can be verified that the most significant exposures were in churches C and E, with $L_{EX,8h}$ values of 85.3 and 86.5 dB(*A*), respectively. However, it is important to point out that the measurement procedure covered only the service in the church, whereas the priests had other activities in the week or other services on the same day. Thus, it was necessary to estimate noise exposure.

TABLE 1. Values Corresponding to the Priests' Noise Dose and Noise Exposure Levels During the Worship and Respective Exposure Time

Church	Dose (%)	Projected Dose (%)	L_{Aeq} (dB(*A*))	T_e (min)	$L_{EX,8h}$ (dB(*A*))
A	1112	5444	102.3	98	95.4
B	1931	7184	103.5	129	97.8
C	2521	8642	104.3	140	98.9
D	1437	5702	102.5	121	96.5
E	2855	11 143	105.4	123	99.5

Notes. Dose—exposure dose related to the duration of one service; projected dose—converted dose value for 8-h exposure; L_{Aeq}—equivalent *A*-weighted sound pressure level; T_e—exposure time, corresponding to the duration of one service; $L_{EX,8h}$—daily noise exposure level, corresponding to an 8-h work shift.

TABLE 2. Values Corresponding to the Worshippers' Dose and Exposure Levels During the Worship and Respective Measurement Times

Church	Dose (%)	Projected Dose (%)	L_{Aeq} (dB(*A*))	T_e (min)	$L_{EX,8h}$ (dB(*A*))
A	11	56	82.8	98	75.6
B	40	148	86.1	129	81.0
C	109	373	90.1	140	85.3
D	33	129	85.4	121	80.1
E	142	553	91.3	123	86.5

Notes. Dose—exposure dose related to the duration of one service; projected dose—converted dose value for an 8-h exposure; L_{Aeq}—equivalent *A*-weighted sound pressure level; T_e—exposure time, corresponding to the duration of one service; $L_{EX,8h}$—daily noise exposure level, corresponding to an 8-h work shift.

In relation to noise exposure variability, some worshippers attended four services per week, according to information collected by one of the authors of this study. Tables 3–4 show the priests' and the worshippers' estimated exposure level, respectively, in *A*-weighted decibels, according to the church analyzed and a hypothetical number of services per week.

On the basis of an estimate for priests who conducted seven services per week, a value of 96.9 dB(*A*) ($L_{EX,w}$) was assigned to church A; for church E, $L_{EX,w}$ = 100.9 dB(*A*). Thus, it was possible to accurately confirm a value well above the recommended limits. Besides, it must be emphasized that the exposure limit recommended was exceeded by the priests in all the churches in a single service. For worshippers attending four services per week, values ranged from 74.6 to 85.5 dB(*A*). In churches A, B and D, $L_{EX,w}$ values below 82 dB(*A*) were registered. Preventive measures were not necessary there.

In church C, the value of $L_{EX,w}$ = 84.4 dB(*A*) was estimated, which indicated the need for preventive and corrective measures, once this region was considered to be of technical uncertainty, according to Standard No. NHO-01 [12]. In church E, where $L_{EX,w}$ = 85.5 dB(*A*), immediate preventive and corrective measures had to be applied according to Standard No. NHO-01.

TABLE 3. Estimated Level of Priests' Exposure, in *A*-Weighted Decibels, by Church and by the Hypothetical Number of Services per Week

	Services per Week									
Church	1	2	3	4	5	6	7	8	9	10
A	88.4	91.4	93.2	94.4	95.4	96.2	96.9	97.4	98.0	98.4
B	90.8	93.8	95.6	96.8	97.8	98.6	99.3	99.8	100.3	100.8
C	92.0	95.0	96.7	98.0	98.9	99.7	100.4	101.0	101.5	102.0
D	89.5	92.5	94.3	95.5	96.5	97.3	98.0	98.6	99.1	99.5
E	92.5	95.5	97.3	98.5	99.5	100.3	100.9	101.5	102.0	102.5

TABLE 4. Worshippers' Exposure Level ($L_{EX,w}$), in *A*-Weighted Decibels, by Church and by the Estimated Number of Services per Week

	Services per Week									
Church	1	2	3	4	5	6	7	8	9	10
A	68.6	71.6	73.4	74.6	75.6	76.4	77.1	77.6	78.2	78.6
B	74.0	77.0	78.8	80.0	81.0	81.8	82.5	83.0	83.5	84.0
C	78.4	81.4	83.1	84.4	85.3	86.1	86.8	87.4	87.9	88.4
D	73.1	76.1	77.9	79.1	80.1	80.9	81.6	82.2	82.7	83.1
E	79.5	82.5	84.3	85.5	86.5	87.3	87.9	88.5	89.0	89.5

4. DISCUSSION

Priests are exposed to health risk during the services due to the high level of noise exposure. These levels carry important noise energy able to produce noise-induced hearing loss. This environment can be compared with loud industrial activities, such as the mechanical and metallurgic ones.

The scenario described in this study is different from some examples cited in the literature, in which areas of churches are classified, concerning the noise, as protection areas. This is the case in Berglund and Lindvall's document [14]. Churches, according to this paper, must be located in areas free of excessive noise which, in our case, is different where churches can be considered as important noise sources and, consequently, causing health risk and annoyance.

The exposure patterns found in this noise evaluation show relevant noise levels comparable to the ones found in the industrial branch. Thus, it is unquestionable the similarities between these two environments, then, due to the noise risk, a hearing conservation program must be implemented.

Data on the volumes of the places may be indicative of the values of reverberation time, magnitude of importance in the aspect of propagation of noise in enclosed spaces. In any way this variable is correlated to the capacity of each church. In the assessment procedure has been shown that there is not a significant correlation between capacity and noise dose.

Relevant limits in this study must be discussed because only the priest's noise exposure was evaluated and there are other church workers who should be assessed to establish a more realistic exposure value based on the homogenous group concept. Other measuring procedures could be carried out to reduce the error once there are noise fluctuations throughout the worship. To all this, it may be interesting to increase the number of samples both of the number of worship and the church workers analysed.

Due both to convenience and viability to this study, only Protestant churches were selected, but high sound pressure levels can also be registered in churches of other creeds. Thus, the noise evaluation could expand to these.

The worshippers' noise exposure must be pointed out for there is the possibility of exceeding the recommended limits. In church E, the one with greater capacity, the weekly noise exposure exceeds the 85 dB(*A*) value for a four-worship analysis. The possible presence of children among the worshippers requires attention and caution, because they show greater susceptibility to loud noise [14].

Probably, the scenario analysed has certain complexity. On the one hand, there is a situation that can be recognized like public health problem, due to high noise levels inside the churches during worship. On the other hand, there is a religious practice settled in this style, with sound amplification to conduct it. Harmonic ways between the acoustical hygiene measures and the religious values must be adopted.

If this behaviour persists, the participation in these worship must be considered like another variable to be inserted in the control confusion in epidemiological studies devoted to clarify the relationship between noise and health in the community.

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