

Logit Analysis of Sound Pressure Levels During Praise and Worship Sessions in Churches: Raising the Spirit or Damaging the Ear?

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Abstract: This study assessed sound pressure levels (SPL) during praise and worship sessions in churches in Makurdi Metropolis, Benue State, Nigeria, to determine compliance with the 97 dBA exposure threshold adopted for a 30-minute worship session and to identify factors associated with excessive SPL exposure. A random sample of 30 churches comprising 12 (40%) Pentecostal and 18 (60%) non-Pentecostal churches was selected. We obtained SPL measurements during praise and worship sessions using a GM1352 Precision Digital Sound Level Meter with a frequency range of 31.5 Hz–8 kHz and a measuring range of 30–130 dBA. We used binary logistic regression to model the likelihood of exceeding 97 dBA based on distance from the sound source, church type, instrument type, and the presence of acoustic materials. Results showed that 18 (60%) churches recorded SPL above 97 dBA, whereas 12 (40%) recorded levels at or below the threshold. The highest recorded SPLs were 111.4 and 111.2 dBA. The overall logistic regression model was statistically significant ($\chi^2 = 25.55$, $df = 4$, $p < 0.001$). Distance from the sound source ($\chi^2 = 21.21$, $p < 0.001$) and church type ($\chi^2 = 5.68$, $p = 0.017$) were significant predictors of exceeding the 97 dBA threshold, whereas instrument type ($p = 0.407$) and acoustic materials ($p = 0.251$) were not significant. The odds ratio for distance was 0.4916 (95% CI: 0.2638–0.9161), indicating lower odds of excessive SPL exposure with increasing distance from the sound source. Church type had an estimated odds ratio of 103.99, although its very wide 95% confidence interval (0.37–28,869.57) indicates substantial uncertainty in the magnitude of the association. The findings indicate that excessive SPL exposure is common during church praise and worship sessions in the

study area, highlighting the need for appropriate sound-level monitoring, strategic loudspeaker placement and acoustic management of worship spaces.

Keywords: Hearing loss, Church Music, Sound Pressure Level, Logit Model, Praise
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1.0 Introduction

Praise and worship, which commonly involve singing, dancing and musical accompaniment, constitute an important component of Christian worship services in Nigeria (Ossaiga, 2024). The practice occurs across different Christian denominations, although the intensity and manner of musical accompaniment may vary among churches. However, the increasing use of amplified contemporary Christian music during worship raises concerns about excessive sound exposure, particularly when sound levels exceed recommended limits. During contemporary worship, musicians and sound engineers may increase amplification levels to enhance the musical experience, potentially resulting in excessive sound exposure among worshippers. Anyiam & Douglas (2019) reported that the increasing use of loud contemporary music in church

worship may have implications for worshippers' hearing and may influence participation among different age groups.”. In some church settings, sound levels during worship may become sufficiently high to interfere with normal communication among worshippers. Repeated or prolonged exposure to high sound pressure levels may increase the risk of noise-induced hearing impairment (Richman, 2013).

Previous studies indicate that excessive sound exposure during church services may pose risks to hearing and general wellbeing. Another survivor reported that the collapse might have been linked to the event that the congregation was singing and dancing, about to take offering “within seconds after the loud sound the roof caved in and trapped scores of the worshippers” (Udoma & Onuegbu, 2016). In the Holy Bible, God instructed the children of Israel to march round the wall of Jericho for six days; once each day. On the seventh day, they were instructed to march round the wall of Jericho seven times and on the seventh time, the priests blew loud and long-lasting sound of trumpets accompanied by the people of Israel's great shout then the wall of Jericho fell down (Joshua 6 :1-20). Again, sound might have probably a contributor to provoke the spiritual exercise to ensure the collapse of the wall. Another impact of sound could be seen in the “hard science” video where one sings a high, long-lasting note to shatter a wine glass (Schrock 2007). Lilly-Tariah *et al.* (2017) investigated sound exposure among worshippers in 30 churches in Port Harcourt, Nigeria. Ten churches each were selected from Catholic, Anglican and Pentecostal denominations. Sound pressure levels were measured during worship services and Mass, with a mean service duration of 3.03 h. The average sound pressure levels in most of the selected churches were reported to be higher than the safety permissible limits of sound by National Environmental and Regulation Act 2007. Folarin (2021) reported that churches and mosques constitute important contributors to environmental noise pollution in Lagos State. (Folarin, 2021). Similarly,

Abankwa (2014) reported that church activities contributed to excessive daytime noise levels in Ghana. The positive use of sound in the development of Science and Technology is well documented in the literature (Carter, 2012; Epstein, 1983; Schrock, 2007; Wess & Meyer, 2020; Sedaca, 2016; Eplett, 2014; Arnold, 2015). Nevertheless, excessive sound exposure can adversely affect hearing, particularly when high sound pressure levels are sustained for prolonged periods. Exposure to excessive sound may result in tinnitus, which is characterized by the perception of ringing, buzzing or other sounds in the absence of an external sound source; in some individuals, these symptoms may persist. Repeated exposure to excessive sound can damage the sensory hair cells and associated structures of the inner ear, potentially resulting in permanent hearing impairment (NIDCD, 2022). Sound pressure level is expressed in decibels (dB) and is commonly measured using a sound level meter. The risk of hearing damage depends on both sound pressure level and exposure duration; therefore, interpret sound levels in relation to the corresponding exposure duration. However, exposure to sounds at or above 85 decibels can cause hearing loss. “Prolonged exposure to sound levels around or above 85 dBA may increase the risk of noise-induced hearing loss.”

Beyond auditory effects, excessive environmental noise has also been associated with annoyance, sleep disturbance, cardiovascular effects, impaired cognitive performance and reduced quality of life and wellbeing (WHO, 2018).”).

Although previous studies have demonstrated that sound levels during church services may exceed recommended exposure limits, important gaps remain in understanding the factors associated with excessive sound exposure during praise and worship sessions. Existing studies have largely focused on measuring and describing sound levels across churches, with limited attention to the factors that predict excessive exposure. In particular, empirical evidence from churches in Makurdi metropolis on the influence of factors such as



distance from the sound source, church denomination, type of musical instruments, and availability of acoustic materials on excessive sound pressure levels remains limited. A statistical assessment of these factors is therefore necessary to identify the characteristics associated with increased exposure risk among worshippers

“Because the potential for hearing damage depends on both sound pressure level and exposure duration, Table 1 presents the maximum recommended exposure duration corresponding to selected sound pressure levels under the exposure criterion adopted in this study.

Table 1: Decibel Exposure Time Guidelines

Continuous dB	Permissible Exposure Time
85 dB	8 hours
88 dB	4 hours
91 dB	2 hours
94 dB	1 hour
97 dB	30 minutes
100 dB	15 minutes
103 dB	7.5 minutes
106 dB	3.75 min (<4min)
109 dB	1.875 min (<2min)
112 dB	.9375 min(<1min)
115 dB	.46875min(<30 sec)

Source:

<http://www.dangerousdecibels.org/virtualexhibit/6measuringsound.html>

The exposure criterion presented in Table 1 provides the basis for classifying the observed sound pressure levels into permissible and excessive exposure categories in the present study. The specific regulatory or technical standard from which these exposure limits were derived should be clearly identified and justified

Therefore, this study aimed to assess sound pressure levels during praise and worship sessions in churches in Makurdi metropolis, Benue State, Nigeria, determine whether the observed levels exceeded the applicable exposure limits, and identify factors

associated with excessive sound pressure level exposure using binary logistic regression. Binary logistic regression is appropriate because the outcome variable is dichotomous, indicating whether the observed sound pressure level is within or above the specified permissible exposure limit. The model enables the likelihood of excessive sound exposure to be estimated as a function of selected explanatory variables (Usu *et al.*, 2024; Udoumoh *et al.*, 2023; Agada *et al.*, 2019; Ugwuowo & Udoumoh, 2010).

The findings of this study may provide useful evidence for church administrators, worship leaders, musicians and sound engineers in managing sound levels during worship services. Identifying factors associated with excessive sound exposure may support practical interventions, including appropriate loudspeaker positioning, maintaining adequate distance from sound sources, and improving acoustic treatment within worship spaces. The findings may also assist public-health and environmental authorities in promoting awareness and appropriate sound-management practices in religious settings

2.0 Materials and Method

2.1 Data and Area of Study

Thirty (30) churches were randomly selected from churches located within Makurdi Metropolis, Benue State, Nigeria. . The selected churches comprised 12 Pentecostal and 18 non-Pentecostal churches Sound pressure levels during Sunday praise and worship sessions were measured using a GM1352 precision digital sound level meter with a frequency range of 31.5 Hz–8 kHz and a measurement range of 30–130 dBA. At each church, sound pressure levels were measured during the praise and worship session using the sound level meter's A-weighting setting. Measurements were taken at predetermined locations relative to the loudspeakers, and the observed sound pressure level was recorded for each measurement point. The sound level meter was calibrated according to the



manufacturer's instructions before data collection

At each church, sound pressure levels were measured at two distance categories from the loudspeakers: (i) ≤ 5 m and (ii) > 5 m. Additional information collected included the type of musical instruments used (local or English), the presence or absence of acoustic effects, and the presence or absence of acoustic materials in the church building. Based on the exposure criterion presented in Table 1, a sound pressure level of 97 dBA

2.2.1 Binary Logistic Regression

Let Y be a binary response variable.

$Y = 1$ if the Sound Pressure Level (SPL) is above 97 dB

$Y = 0$ if the Sound Pressure Level (SPL) is less than or equal to 97 dB.

Given a dichotomous dependent variable y which is determined by a set of predictor variables contained in vector x' so that

$$\log \text{it}(p) = \log \left(\frac{p}{1-p} \right) \quad (1)$$

where $\frac{p}{1-p}$ is the odd ratio, p is the probability of high SPL.

$$p_i(x) = \frac{\exp\{\alpha + \beta x'_i\}}{1 + \exp\{\alpha + \beta x'_i\}}; -\infty \leq x \leq \infty \quad (2)$$

where p_i is the probability the i^{th} risk factor, where the odds are defined as the ratio of the probability of excessive SPL exposure to the probability of non-excessive SPL exposure. Then

$$\frac{p_i(x)}{1-p_i(x)} = \exp\{\alpha + \beta x'_i\} \quad (3)$$

Taking the natural logarithm on both sides of Equation (3), we have

$$\log_e \left(\frac{p_i(x)}{1-p_i(x)} \right) = \alpha + \beta x'_i \quad (4)$$

where x' is the vector of exogenous variables.

The parameters in the model can be estimated by the method of maximum likelihood.

Suppose $X = x_i, i = 1, 2, 3, \dots, n$ and the probability of success is p and failure $1-p$,

Let

$$\text{Let } y_i = \begin{cases} 1 & \text{if SPL is above 97dB} \\ 0 & \text{if SPL is less than or equal to 97 dB} \end{cases} \quad (5)$$

Then Y_i has a Bernoulli distribution with mean p and variance $p(1-p)$. The probability function for the random variable Y_i is

$$f(y_i) = p^{y_i} (1-p)^{1-y_i}; i = 1, 2, 3, \dots, n \quad (6)$$

To estimate the parameters, we obtain the likelihood function

$$L(y_i, \alpha, \beta) = \prod_{i=1}^n f(y_i) = \prod_{i=1}^n p^{y_i} (1-p)^{1-y_i} \quad (7)$$



The values of α and β that will maximize $L(y_i, \alpha, \beta)$ will also maximize $\ln L(y_i, \alpha, \beta)$, we have

$$\log_e L(y_i, \alpha, \beta) = \sum_{i=1}^n [y_i \log_e p + (1 - y_i) \log_e (1 - p)] \quad (8)$$

The likelihood function after some simplification steps is

$$\log_e L(y_i, \alpha, \beta) = \sum_{i=1}^n [-\log_e \{1 + \exp(\alpha + \beta x_i')\} + y_i(\alpha + \beta x_i')] \quad (9)$$

To estimate the parameters in the model that maximize the logarithm of the likelihood function, we differentiate Equation (9) partially with respect to α and β , setting the results respectively to zero, we have

$$\frac{\partial \log_e L(y_i, \alpha, \beta)}{\partial \alpha} = \sum_{i=1}^n [y_i - p(x_i)] = 0 \quad (10)$$

Similarly,

$$\frac{\partial \log_e L(y_i, \alpha, \beta)}{\partial \beta} = \sum_{i=1}^n [y_i - p(x_i)] x_i = 0 \quad (11)$$

Equations (10) and (11) could be evaluated using any numerical procedure to obtain the desired results.

The empirical model may be represented as

$$\log_e \left(\frac{p}{1-p} \right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon \quad (12)$$

where p is the probability of high SPL, the β_i 's are regression coefficients, and X_i 's, $i = 1, 2, \dots, 4$ are the independent variables namely: distance from source of sound, church type, type of musical instruments, and acoustic effect respectively.

2.2.2 Goodness of fit and Model Adequacy Checks

Model adequacy was assessed by comparing the null model, which contains only the intercept, with the full model containing the specified predictor variables. The Null model -2 Loglikelihood is given as;

$$D_0 = -2 * \log_e (L_0) \quad (13)$$

where L_0 is the likelihood of obtaining the observations if the independent variables have no effect on the outcome.

The Full model -2 Loglikelihood is given as;

$$D = -2 * \log_e (L) \quad (14)$$

where L is the likelihood of obtaining the observations if the independent variables have effect on the outcome.

The difference in deviance between the null and full models provides a likelihood-ratio chi-square statistic for testing whether the predictor variables, considered jointly, significantly improve model fit. A p-value less than 0.05 indicates that the full model provides a statistically significant improvement over the null model, suggesting that at least one predictor is associated with the probability of excessive SPL exposure.

The Chi-square statistic for this test is computed by;

$$\chi^2_{HL} = \sum_{k=1}^K \frac{(O_k - E_k)^2}{E_k (1 - E_k / n_k)} \quad (15)$$

where O_k and E_k represent the observed and expected events, n_k is the number of observations for the k^{th} decile group and K the number of groups. The number of degree

The Hosmer – Lemeshow test



of freedom is $K - 2$. For the Hosmer–Lemeshow test, a p-value less than 0.05 provides evidence of lack of fit, whereas a p-value greater than 0.05 indicates that there is insufficient evidence to conclude that the model fits poorly. A p-value less than 0.05 indicates that the corresponding regression coefficient differs significantly from zero, suggesting that the predictor is significantly associated with the outcome (Hosmer–Lemeshow 2000).

Wald Statistics

The Wald's statistic tests the significance of model parameters. It determines whether or not an independent variable stays in the model as it tests if the associated model parameter differs significantly from zero. The Wald's statistic is computed as the regression coefficient divided by its standard error squared:

$$W = \left(\frac{\beta}{SE}\right)^2 \sim N(0,1) \quad (16)$$

where β = the associated regression parameter and SE = Standard Error

If $p\text{-value} < 0.05$, then there is evidence to conclude that the independent variable differ significantly from zero and should be included in the model.

Odds Ratio (O.R.)

Odds ratios are obtained by exponentiating the estimated logistic regression coefficients. Thus, from Equation (12)

$$\text{Odds} = \frac{p}{1-p} = e^{\alpha} e^{\beta_1 X_1} e^{\beta_2 X_2} e^{\beta_3 X_3} e^{\beta_4 X_4} \quad (17a)$$

$$\text{Or } OR_j = e^{\beta_j} \quad (17b)$$

If β_j is positive, then $OR_j > 1$, indicating increased odds of excessive SPL exposure relative to the reference category. If $\beta_j < 0$, then $OR_j < 1$, indicating reduced odds relative to the reference category..

4.0 Results and Discussion

Table 2 shows that, of the 30 selected churches, 12 (40%) were Pentecostal and 18 (60%) were non-Pentecostal.. Table 2 further shows that 18 (60%) churches recorded sound pressure levels above the 97 dBA exposure threshold, whereas 12 (40%)

recorded levels at or below the threshold.. The highest recorded sound pressure levels were 111.4 and 111.2 dBA. Such high sound levels may interfere with verbal communication and may increase the risk of adverse auditory effects with sufficient exposure duration. Schultz (2016), citing observations attributed to David Gauger, reported that sound levels exceeding approximately 90 dB may discourage congregational participation. If there is no participation then there is no worship (Schultz, 2016). Although music can enhance participation and engagement during worship, excessive amplification may compromise auditory comfort and communication, highlighting the need for appropriate sound-level management (Cosby, 2022). In the words of Adarkwa (2015) “music instructs the mind, inspires the emotions, and challenges the will”. In other words, music rejuvenates the total man; spirit, soul and body. Hence, in participatory praise and worship sessions human spirit should be raised to offer an acceptable worship to God as prescribed in the Holy Bible (John 4: 23).

Regarding musical instrument type, 24 (80%) churches used English instruments, whereas 6 (20%) used local instruments. The presence or absence of acoustic materials was also assessed as a potential factor associated with excessive sound pressure levels. Acoustic materials included items such as fabrics, carpets, curtains and acoustic foams that may reduce sound reflection and reverberation within worship spaces (Alibaba and Itontei 2016). From the data, 10 (33%) churches had acoustic materials while 20 (67%) did not have acoustic materials.

Fig. 1 shows that 12 (40%) observations were at or below the 97 dBA exposure threshold, whereas 18 (60%) exceeded the threshold while eighteen (18) are out of the acceptable SPL which correspond to 40% and 60% respectively. In other words, 60% of churches considered operated outside the permissible SPL.

This indicates that a substantial proportion of worshippers may have been exposed to sound



Total	29	40.3807			
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Table 4: Model Summary

Deviance R-Square	Deviance R-Square (Adj)	AIC
63.26%	53.36%	24.83

Table 4 presents the summary statistics of the goodness of fit test on the logistic regression model using R^2 , adjusted R^2 and Akaike information Criteria (AIC). R^2 value in Table 3 indicates that the model had a deviance-based pseudo- R^2 of 63.26%,

indicating a substantial improvement in deviance relative to the null model. An adjustment of the R^2 statistic based on the number of independent variables further confirms that the adjusted deviance R^2 was 53.36%, reflecting the model's fit after accounting for the number of predictors. The model had an Akaike Information Criterion (AIC) of 24.83, which can be used for comparison with alternative models fitted to the same data.

Table 5: Coefficients

Term	Coefficient	SE Coefficient	VIF
Constant	6.25	3.26	
Distance	-0.710	0.318	4.01
Church Type	4.64	2.87	4.35
Type of Instruments	1.50	1.85	1.48
Acoustic Effect	-2.25	2.19	1.37

Table 5 presents estimates of the Logistic Regression coefficients. The VIF values for the predictors ranged from 1.37 to 4.35. These values do not indicate severe multicollinearity among the predictors based on the adopted VIF criterion. The negative coefficient for distance indicates that increasing distance from the sound source is associated with lower log-odds of exceeding the 97 dBA exposure threshold. The negative coefficient for acoustic materials indicates lower estimated log-odds of exceeding the 97 dBA threshold when acoustic materials are present, although this association was not statistically significant ($p = 0.251$). The positive coefficients for church type and instrument type indicate higher estimated log-odds of exceeding the 97 dBA threshold for the coded category relative to its reference category. Table 6 presents the odds ratio for distance from the sound source. The estimated odds ratio was 0.4916 (95% CI: 0.2638–0.9161). The odds ratio of 0.4916 indicates that a one-unit increase in the coded distance variable was associated with approximately 50.8% lower odds of

exceeding the 97 dBA threshold, holding the other predictors constant. Similarly, Odds Ratios for categorical predictors are presented in Table 7. The estimated odds ratio for church type was 103.99, suggesting substantially higher estimated odds of exceeding the 97 dBA threshold for the coded Pentecostal category relative to the non-Pentecostal reference category. However, the 95% confidence interval was extremely wide (0.37–28,869.57), indicating substantial uncertainty around the estimate; therefore, the magnitude of the association should be interpreted cautiously. The estimated odds ratio for instrument type was 4.47, suggesting higher odds of exceeding the 97 dBA threshold for the coded English-instrument category relative to the local-instrument reference category. However, the association was not statistically significant, and the 95% confidence interval was wide (0.12–168.56). The odds ratio for acoustic materials was 0.1052 (95% CI: 0.0014–7.7132), suggesting lower estimated odds of exceeding the 97 dBA threshold when acoustic materials were present; however, the



association was not statistically significant ($p = 0.251$). Table 8 presents more results on model adequacy check using the Deviance, Pearson Chi-Square, and Hosmer and Lemeshow Statistics. The Deviance, Pearson

and Hosmer–Lemeshow goodness-of-fit tests were not statistically significant ($p = 0.945$, 0.975 and 0.963 , respectively), indicating no evidence of significant lack of fit between the fitted model and the observed data

Table 6: Odds Ratios for Continuous Predictor

Variable	Odds Ratio	95% Confidence Interval
DISTANCE	0.4916	(0.2638, 0.9161)

Table 7: Odds Ratios for Categorical Predictors

Level 1	Level 0	Odds Ratio	95% CI
Church Type			
1	0	103.9900	(0.3746, 28869.5711)
Instrument			
1	0	4.4683	(0.1185, 168.5578)
Acoustic Effect			
1	0	0.1052	(0.0014, 7.7132)

Odds ratio for level 1 relative to level 0

Table 8: Goodness-of-Fit Tests

Test	DF	Chi-Square	P-Value
Deviance	25	1.83	0.945
Pearson	25	13.10	0.975
Hosmer-Lemeshow	8	2.47	0.963

5.0 Conclusion

This study assessed sound pressure levels (SPL) during praise and worship sessions in 30 churches in Makurdi Metropolis, Benue State, using descriptive statistics and binary logistic regression. The results showed that 18 (60%) of the selected churches recorded SPL above 97 dBA, the exposure threshold adopted for a 30-minute worship session, while 12 (40%) recorded levels at or below the threshold. This finding indicates that a substantial proportion of worshippers may be exposed to sound levels that could increase the risk of noise-induced hearing impairment with repeated or prolonged exposure.

The binary logistic regression analysis showed that distance from the sound source and church type were significantly associated with the likelihood of exceeding the 97 dBA threshold. Worshippers located farther from the sound source had lower estimated odds of exposure above the threshold, while the odds of high SPL were higher in Pentecostal

churches than in non-Pentecostal churches. Although the presence of acoustic materials was associated with lower estimated odds of excessive SPL exposure, this relationship was not statistically significant. Similarly, instrument type was not a statistically significant predictor of excessive SPL exposure.

Based on these findings, churches should adopt appropriate sound-level management practices during praise and worship sessions. Worship centres should incorporate suitable acoustic treatment, position loudspeakers strategically away from worshippers, and regularly monitor SPL during worship services. These measures could help reduce excessive sound exposure while maintaining an appropriate acoustic environment for congregational participation.

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Declarations

Conflict of Interest

The authors declared no conflict of interest

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Ethical consideration

Has been declared in section 2.7

Data Availability

Data shall be made available upon request

Author Contributions

Enobong Francis Jonathan contributed to conceptualization, data collection, methodology, analysis, and manuscript preparation. Jonathan Atsua Ikughur contributed to study design, measurements, data analysis, and revision. Clara Emmanuel Uko contributed to literature review, interpretation, editing, and critical review. All authors approved the final manuscript.

