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"Impacts of Leisure Activity Noise Levels, Revised (A Case Study)"

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Abstract

A 1991 article in International Journal of Industrial Ergonomics discussed the effects of leisure noise levels on workers' hearing loss. With an observed change in noise level preferences, this study examined measured observations to determine that leisure noise levels were consistent with the data collected in 1990. However, in some indoor leisure environments levels have increased. This study's purposes was to document current leisure activities and determine if the leisure noise level preferences and tolerances are indeed higher than Occupational Health and Safety Administration (OSHA) and International Standards Organization (ISO) guidelines. Industries have taken steps to comply with OSHA and ISO guidelines; however, churches, bars, and sporting events examined are not subject to the guidelines. Noise samples using a Quest SPL (2800) calibrated dosimeter were collected. Average peak levels were as follows: churches (115.24 dB (σ = 5.06 dB)), bars (114.08 dB (σ = 8.3 dB)), and athletic events (117.57 dB (σ = 5.6 dB)). Any noise level above 115.0 dB for any exposure time exceeds the OSHA and ISO allowances. Changes of 3 dB can more than double the noise level depending on frequency. Working adults exposed to these levels after a day's work in OSHA-controlled environments are exceeding allowable exposure. Thus the risk of permanent threshold shift is increased. Although a child's auditory system is fully developed at birth, early exposure to noise levels that exceed the health and safety standards are at higher risk of permanent threshold shift at an earlier age than their parents.

Keywords: Leisure noise levels, permanent threshold shift, allowable noise levels

1. Introduction

Eight hours is the standard measure for industrial ergonomics at work[6]. Given certain industries, eight of every twenty four can be spent exposing oneself to excessive noise levels. While not always considered a basic principle of job safety, hearing loss and hearing impairment have recently been a focal point of industry research. While many manufacturing companies incur the liability, and associated costs, related to hearing loss and impairment, the root of this damage has not firmly been attributed to the workplace. Prior noise research, by organizations such as the Occupational Health and Safety Administration (OSHA) and International Standards Organization (ISO), found that the potential dangers of noise levels in the workplace. This study, a revised/updated article based on, "Impacts of leisure activity noise levels on safety procedures and policy in the industrial environment"[2], focused on the dangers of incurred hearing damage outside of the work environment: in leisure settings. Through the comparison of data collected in leisure activities in 1990 to data collected in 2012, this case study validates the concern of cumulative noise exposure and its role in hearing impairment and permanent threshold shift.

OSHA and ISO regulations set forth guidelines for noise exposure in the workplace. Table 1 is a chart of exposure time to noise level and equivalent noise exposures to noise levels. Decibels, used in this study as a noise measurement, are the measure of sound-pressure intensity[1]. The Occupational Safety and Health Act of 1970[7] brought into existence both OSHA and National Institute for Occupational Safety and Health (NIOSH) with the charge to examine all aspects of working conditions, including noise levels. OSHA provides the following example for how the cumulative damage incurred by noise levels occurs: *OSHA allows 8 hours of exposure to 90 dB but only 2 hours of exposure to 100 dB sound levels. NIOSH would recommend limiting the 8 hour exposure to less than 85 dB. At 100 dB, NIOSH recommends less than 15 minutes of exposure per day.* As illustrated in table 1, both OSHA and the American Congress of Governmental Industrial Hygienists (ACGIH) have policies on allowable noise levels and corresponding times. This accumulation of hearing damage indicates that incurred noise damage at work and incurred noise damage after-hours are not two separate instances of damage, but instead the logarithmic combination of the two. Since noise data is logarithmic rather than linear, exposure times in excess of eight hours, regardless of whether it is work or leisure, increases the permanent threshold shift potential. Konz, in his book Work Design, Occupational Ergonomics (2004), describes ear hair cells, attached to the nerve endings, as blades of grass which sustain damage in similar patterns to hearing damage. As one would walk on grass continuously, or "wears the path", and not allow for regrowth, the grass does not have the opportunity to "spring back up". In a similar fashion, ear cells that are not enabled to "bounce back" (a temporary threshold shift). Through a lack of noise absence, these cells will not be able to grow or even sustain growth[2]. Allowing sufficient time between high levels of exposure and recovery time is critical.

Table 1- Maximum daily noise exposure OSHA & American Congress of Governmental Industrial Hygienists (ACGIH)

Duration/Day (hours)	**OSHA**	**ACGIH**
16	85 dB	80 dB
8	90 dB	85 dB
4	95 dB	90 dB
2	100 dB	95 dB
1	105 dB	100 dB
.5	110 dB	105 dB
.25	115 dB	110 dB
.125	-	115 dB

Noise pollution and its correlation to hearing damage have been studied and assessed as early as 1971[10], but have recently changed focused from working hours to leisure hours. What is described as "social noise phenomenon", there is the current theory that noise levels greatly exceed comfortable noise levels in social settings [3]. This theory stipulates that "high levels of noise allowed young people to interact with members of the opposite sex in an environment which does not require the use of extensive social skills"[2] .To further look into this observation, leisure noise (in this study) was observed in relationship as well as activity.

Leisure activities are broken down into the following categories: nightlife, church, and sporting endeavors. Further, each category is divided into subsets: nightlife is subcategorized into 21-30 age bars and 30 + age bars; churches are subdivided into contemporary and traditional churches; and sporting endeavors are subcategorized into men's basketball and women's volleyball. Additional noise level data was also taken at six movies theatres and with three pieces of outdoor equipment, as well as in three automobiles.

Noise levels recorded in a manufacturing plant in 2012, found through prior research, had an average peak level of 119.9 dbA with a standard deviation of 3.27 dbA. Leisure activities in this study, on the other hand, had peaks around 125 dB; whereas OSHA has determined that sound levels exceeding 115 dB should not be exposed to an ear for more than 1 minute[6]. Furthermore, most manufacturing companies not only educated on the hazard of noise, but also provide hearing protection equipment. To the detriment of social education, noise sustained during leisure time activities is not advocated sufficiently so that the average person grasps the rick of potential hearing loss. By illustrating the activities principally attributable to the risks of extended and exceeding noise levels, this study aims to educate on the leisure hours where hearing protection is not provided, medical insurance is not covered, and hearing and the hearing of the next generations are at a much higher risk than twenty years ago.

2. Methodology/ Experimental Protocol

This study examined thirty nine leisure time activities, further broken down into the following categories: four (4) 21-30 age bars, four (4) 30+ age bars, six (6) contemporary churches, four (4) traditional churches, five (5) movies, four (4) men's basketball games, four (4) women's volleyball games, three (3) pieces of outdoor equipment, and three (3) automobile radio readings. All data recordings occurred between September 28th, 2012 and January 24th, 2013 in Western North Carolina.

To be able to assess noise levels and compare to one another, this experiment required the utilization of the following two devices: GenRad 1565-B Sound-Level Meter (figure 1) and a Quest Electronic Micro-15 Permissible Noise Dosimeter (figure 2). The Micro-15 Dosimeter device was employed to measure multiple noise levels, including peak levels, for the following activities: bars, churches, sporting endeavors, movies and outdoor appliances. The GenRad 1565-B device was used to measure peak levels in automobiles.

Figure 1- GenRad 1565-B Sound-Level Meter

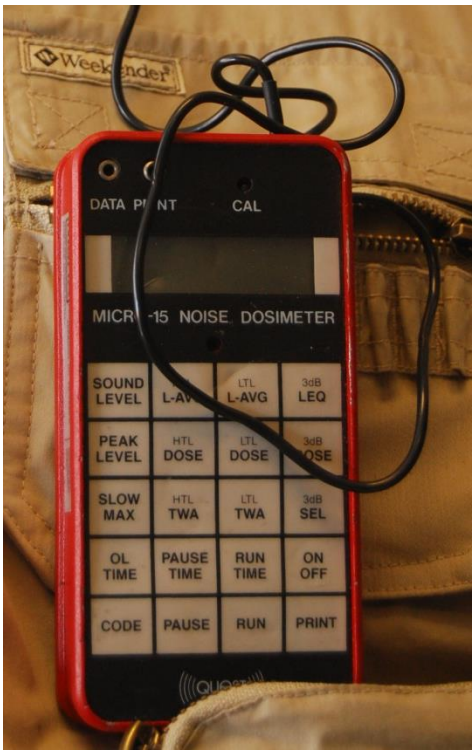

Figure 2- Quest Electronic Micro-15 Noise Dosimeter

The Micro-15 Dosimeter device provided the following noise level data points: HTL L-AVG, LTL L-AVG, 3dB LEQ, Peak, HTL Dose, 3dB Dose, Slow Max, HTL TWA, LTL TWA, 3dB SEL & Run Time, detailed in table 2. For the purpose of this study, peak noise levels and 3db SEL noise data was utilized as the most relevant and

applicable noise reading tools. Both instruments were calibrated prior to each reading, to ensure effectiveness of reading. The dosimeter was concealed inside of a clutch (small purse), with the microphone located outside of the purse. The microphone was placed as close to the ear as possible for accuracy of what the ear was in taking as true noise levels. To experience each of these leisure activities, an attempt was made at each event to stay what would be a traditional amount of time. For example, a church would naturally run between 45 minutes and 1.25 hours whereas a movie was recorded for between 1.5 hours to 2.5 hours. The levels were then recorded on a data collection sheet later recorded in Microsoft Excel, Statistical Analysis Software and Satterwaite's Approximation[8].

Table 2- Description of Noise Measures

Measure of Noise	**Description**
HTL L-AVG LTL L-AVG	L-AVG is the average sound level for the sample period. HTL stands for high threshold level. The high threshold is 90 dBA, which means anything below 90dBA is not recorded. This is mainly used to demonstrate compliance with the OSHA PEL of 90dBA.
3dB LEQ	The integrated average sound level measured in decibels with a 3 dB exchange rate, no time constant and no threshold.
Peak	The highest peak level recorded during the sampling period. The OSHA standard for impact/impulse noise is 140 dB.
HTL Dose	The accumulated noise dose expressed as a percent of the allowable dose for all noise above the threshold level. It is a percentage of the allowable limit. HTL is for a threshold of 90 dBA.
3dB Dose	The percent dose with a crtterion level selected at 85 dBA
Slow Max	The maximum level attained measured on SLOW response.
HTL TWA LTL TWA	This tells you the 8 hour time weighted average noise exposure. This is used if the sample period is less (or in some cases longer) than an eight hour period. It assumes zero exposure for any un-sampled period of time and calculates the TWA. HTL is for a threshold of 90 dBA, and LTL is for a threshold of 80 dBA.
3dB SEL	The total sound exposure level in decibels integrated over 1 second.
Run Time	Time that dosimeter was kept recording

To fairly compare each reading to another in its subcategory and from category to category, statisticians from the University of North Carolina at Asheville were consulted in the analysis of the data. Because decibels are logarithmic by nature[6], a normalcy test is required to ensure that each data point could be compared to another. To complete this, two statistical approaches were taken to ensure the process. The first is that each data point was also converted to a natural log (ln). Secondly, both raw data and natural logs of raw data were analyzed through Statistical Analysis Software (SAS) for homogeneity and normality using Levene's and 1's variance at the statistical significance level of $\alpha = .05$. Because of the small sample size and the large variation, Messy Data procedures, specified by Milliken & Johnson (1984) were used. To determine if a comparison was statistically significantly different, the significance level $\alpha = 0.05$ was used for all statistical tests.

While it should be noted that the group size (n) is small for these types of test, the homogeneity test of variances and tests for normality confirmed that the collected data could be compared together. Each data point was then compared to all other data points within the subcategory and each category's mean and standard deviation were compared to all other categories. Since the original publication, "Impacts of leisure activity noise levels on safety procedures and policy in the industrial environment in 1991, it was analyzed at the same statistical significance level ($p= 0.05$) that certain leisure activities have dramatically increased. The Welch Anova test, run through SAS, illustrates the mean and standard deviation can be compared through categories (correcting for variance associated with logarithmic data) with a p-value of 0.0543. With this in mind, assumptions of normality are valid.

3. Results

A total of thirty nine noise readings were taken for leisure activities, in the following listed categories and subcategories. The mean for all data readings was 114.24 dB, with a standard deviation of 7.31 dB. Table 3 shows the number of readings, means, and standard deviations for each subcategory. Samples were taken at random time

intervals, which fit with the leisure activity construct and norm. Important to note is the drastic increase in mean from the 1991 publication on leisure noise levels, from 99.4 dB[2] to 114.24 dB. Additionally, three readings were taken with the spot meter in three separate automobiles. Each car was turned on and a spot recording was measured to see where noise levels were left on the radio. The following are the three peak spot readings: Automobile 1: 78 dB, Automobile 2: 69 dB , Automobile 3: 86 dB.

Table 3- Peak & 3db SEL Noise Levels in 2012 for Leisure Activities (Subcategories)

Category	Sub-Category	No. of Readings	Peak-Mean	Peak-Std. Dev	3db SEL-Mean	3db SEL-Std. Dev
Bar	21-30	4	116.60	8.832	123.88	10.25
Bar	30+	4	111.55	8.046	118.47	0.77
Church	Contemporary	6	117.15	1.152	119.10	4.35
Church	Traditional	4	112.38	7.504	113.16	3.23
Movie	NA	5	113.36	7.327	115.74	7.91
Sports	Men's Basketball	4	122.15	3.659	124.95	3.39
Sports	Women's Volleyball	4	112.99	2.047	122.71	1.40
Equipment	NA	3	103.97	9.965	111.68	7.42

4. Analysis

Table 4 illustrates the means and standard deviations between categories (bars, churches, sports, movies, & equipment) as overall types of leisure activities with the corresponding data. Important to notice is the order in which leisure activities go from quietest to loudest: power equipment, movies, bars, churches and then finally sports. While there is an obvious and clear difference in decibel levels, when comparing category to category, this difference is dissolved statistically. At the statistical significance level of $\alpha = .05$, there are no significant difference for peak noise levels.

Table 4- Peak and 3db SEL Noise Level for 2012 Leisure Activities (Categories)

Category	No. of Readings	Peak- Mean	Std. Dev	3db SEL-Mean	3db SEL-Std. Dev
Bar	8	114.08	8.274	121.17	7.33
Church	10	115.24	5.058	116.72	4.84
Sports	8	117.57	5.613	123.83	2.68
Movie	5	113.36	7.327	115.74	7.91
Equipment	3	103.97	9.965	111.68	8.07

Leisure noise levels were found to be 14.84 dB louder than leisure noise recorded in 1990[2]. Through the comparison of noise data collected in 1990 and that of this study, table 4 shows the direct comparison of the noise levels, the increase and the significance of this increase. For the purpose of this table, discotheques and bars were compared, concerts and contemporary churches (all having a concert aspect to the service) were compared, and woodworking and equipment were compared. The greatest difference in noise levels is the 14.58 jump in decibels in bars from 1990 to 2012, followed by a 7.55 dB increase in concerts in the 1990s to contemporary churches in 2012. With the logarithmic nature of decibels, this quantitative increase in decibels is much greater than raw numbers illustrate. While the equipment noise levels did increase by 6.07 dB in the last two decades, it is important to note

that during the recording of this data, the researcher was asked to put on ear protection (as did the employee) and was told that the noise levels could be damaging to hearing.

Table 5- Comparison of 1990 noise data to 2012

Category	1990 peak mean (dB)	1990 peak std. dev (dB)	2012 peak mean (dB)	2012 peak std. dev (dB)	Difference	Significance
Discotheques/Bars	99.5	5.9	114.08	8.274	14.58	Highly significant; p=.005
Concerts/Contemporary Churches	109.6	5	117.15	1.152	7.55	Highly significant; p=.005
Woodworking/Equipment	97.9	6.59	103.97	9.965	6.07	Not significant

Figure 3 illustrates the significance levels between the data collected in 1990 to the data collected in 2012. As the data was statistically proven, through Satterwaite's approximation, we can see a note-worthy increase in noise levels in discotheques and bars, as well as concerts and contemporary churches. No statistical correlation was found between noise level data collected in 1990 and 2012 of woodworking and power equipment.

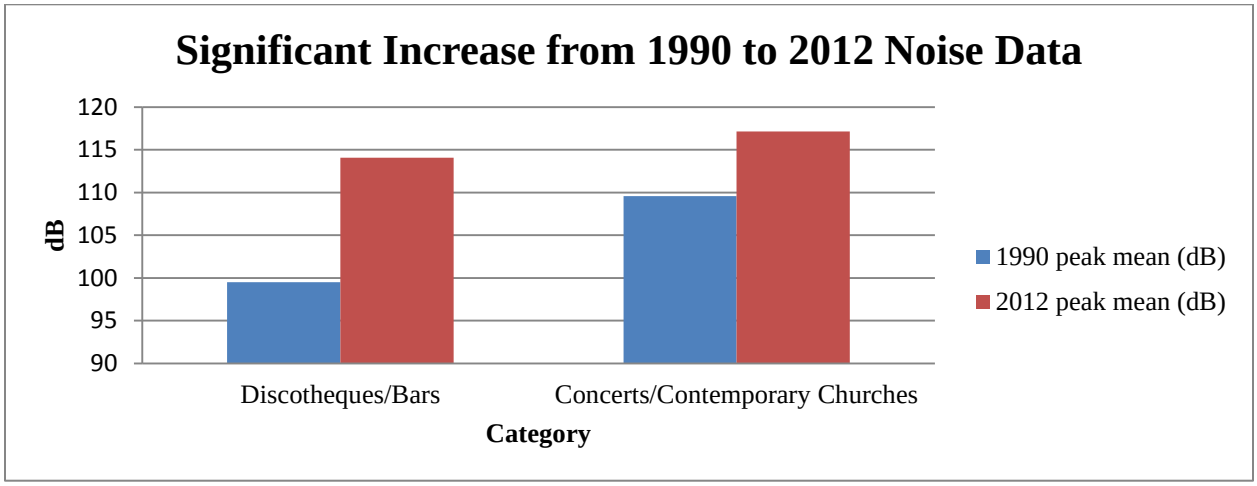

Figure 3. Significance Levels between 1990 and 2012 Data

5. Discussion

One single acute exposure of exceedingly high noise levels has the potential to shift auditory threshold[1]. Noise, a basic part of everyday interactions and lifestyles, has the potential to cause great damage, if not properly understood and without preventative protection. In the introduction section, in table 1, the Occupational Health and Safety Administration (OSHA) and American Congress of Governmental Industrial Hygienists (ACGIH) highlight the regulations on decibel readings and exposure time. Comparing these regulations to the collected data, the assumption would be that power equipment could not be used for more than one hour and attending church could not exceed fifteen minutes. Further, these assumptions are only viable if the individual has not already accumulated hearing damage, from work or leisure, in the same day.

It has been observed by Brown in 1990 that employees that work in noisy environments tend to participate in equally noise leisure time activities. Further studies have even shown that, at times, the noise incurred both at work is unavoidable and can encourage higher leisure noise levels as well. A study conducted in in Finland with military personnel showed that work associated noise, such as "cannons, mortars, bazookas, missiles, and rockets" were inescapable and played a role in the level of noise that these military personnel choose to engage in in their leisure

activities. The study concluded with the projection of one of five of these individuals was at risk of experiencing hearing loss during leisure-time activities[5].

Additionally, studies have been conducted on the excessive noise level in movie theatres. Warszawa's study conducted in 2010 followed twenty five films, breaking down the time exposure to each of the decibel brackets provided by OSHA. This study, coupled with K. Osborne's study shows that a majority (88%) of participants appreciated louder noise levels at movie theatres, as it 'added' to the experience[9]. Further, studies have shown correlation between age and gender and desirable noise level. Referred to as the "social noise phenomenon", it has been observed that younger individuals prefer louder music in social setting because it allows for social interaction without as many conversations. This was supported by looking at age brackets and preferences, with the 15-19 age group listening to music at the loudest level (95.3 dbA , (σ = 8.1 dB)) $_4$. This crucial discussion to be had about hearing protection and initiative has begun in certain arenas, such as New York City. Mayor Michael Bloomberg has begun the process of investing $250,000, from the Health Department's Fund for Public Health, into education about the dangers of ear buds and excessive noise levels[13].

6. Conclusion

This article hopes to bring a greater sense of understanding to the unintentional and irreparable damage that can result in permanent threshold shift during activities that are considered to be fun, engaging ways to enjoy time away from work. While OSHA, ISO, and other agencies provide education, policies, and protection to noise levels and incurred damage at the workplace, what any given individual takes part in in their personal lives comes with no government agency to provide safety information or regulations. Unfortunately, the necessary education to protect leisure hearing has not increased at the same increment that noise preference levels have. This study not only indicates that decibel readings and associated noise levels have increased greatly in just two decades. Yet, further, it illustrates that the younger generations openly welcome the increase in noise levels without a full appreciation for the potential consequences. The contrary, studies are showing the youth not only are undereducated in noise level damage but also prefer to have increased levels of noise for the experience and for the benefits of "social noise phenomenon". With noise levels that have been deemed unsafe for any amount of time, the time for education and steps to help protect hearing has come and is going to play an important role in what we consider in the eternal debate of current risk versus long-term reward.

7. References

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