NOISE AND AGE RELATED HEARING LOSS – A STUDY OF 40123 SOUTH AFRICAN GOLD MINERS

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ABSTRACT:

This retrospective cohort study aimed to describe the differential effect of noise exposure and age-related hearing loss in a large sample of South Africa gold miners.

Audiological data of 40123 miners were investigated. Data of a non-noise-exposed control group (n=6162) and group exposed to underground noise (≥ 85 dB A (TWA) (n=33961) were included. Two homogenous exposure groups (HEG) were also selected for analyses, the driller group (n=4399) and the administration group (n=2211). Participants were categorised in terms of noise exposure; age and race.

Significantly different thresholds (worse for underground noise group) with respect to the median for all frequencies after adjusting for age was evident between the noise exposed and control groups (ANCOVA). The largest differences in hearing thresholds between the noise-exposed and control groups were observed at 3 and 4 kHz in the age group 36 to 45 years. Black males had significantly better high-frequency hearing compared with white male counterparts but significantly worse low-frequency hearing.

Age was the most important influence on hearing thresholds for the noise and control groups. Race was shown to be a significant factor determining susceptibility to NIHL and ARHL.

Key Words: NIHL; ARHL; South Africa; Mine Workers; Homogenous exposure groups; Noise Exposure

List of Acronyms:

ARHL	Age related hearing loss
COIDA	Compensation for Occupational Injuries and Diseases Act, No. 130 of 1993. South Africa
dB A	Decibel A-weighted

dB HL	Decibel hearing level
dB SPL	Decibel sound pressure level
HEG	Homogenous exposure group
kHz	kiloHertz
NIHL	Noise-induced hearing loss
OEL	Occupational exposure level
RSA	Republic of South Africa

INTRODUCTION

The processes associated with mining generate tremendous noise as a result of activities including percussion drilling, blasting and crushing of ore which is often exacerbated by confined and reflective spaces (MHSC, 2005). A World Health Organization study, based on United States of America (USA) data, estimated that the industry with the highest proportion of workers exposed to hazardous noise was mining with an estimated 0,85 of all the production workers and laborers exposed to noise levels at or above 85 dB A (TWA) (Nelson, et al., 2005a).

In South Africa mining is the country's largest industry employing 5.1% of all workers in the non-agricultural, formal sectors of the economy, a reported total of 357 000 employees in 2012 (Mwape, Roberts, & Mokwena, 2007). In 2010 South Africa was the world's fourth largest gold producer with gold ore reserves estimated at 6000 tons (United States Geological Survey, 2010; Chamber of Mines, 2012). The country is home to some of the world's largest mining companies, such as Anglogold-Ashanti, Goldfields and Harmony Gold. About 95% of South Africa's gold mines are underground operations. The mean noise exposure levels in the South African mining industry were recently reported to range from 63.9 dB A to 113.5 dB A (TWA) with approximately 73.2% of miners in the industry exposed to noise levels of above the legislated occupational exposure level (OEL) of 85 dB A (TWA)(Edwards, Dekker, & Franz, 2011). The South African Chamber of Mines estimated that 3.1 out of every 1000 workers have Noise-Induced Hearing Loss (NIHL) (Chamber of Mines, 2012).

Several factors play a role in individual susceptibility (vulnerability) to NIHL. These factors range from accompanying environmental factors such as non-occupational noise exposure and vibration, and biological factors such as smoking, age, gender, genetics, ototoxic drugs and illnesses such as tuberculosis (Pyykkö et al, 2007; Brits, et al, 2011). In South Africa a very large porportion of the mining workforce is black (referred to as African) compared to a much smaller white group. To date only one large scale study has been done investigating NIHL in South African mine workers. This study investigated NIHL in a cohort of white South African male mine workers (N=2667) (Hessel & Sluis-Cremer, 1987). As no black or female workers were included in this cohort, comparisons between these groups and respective susceptibility to NIHL were unavailable.

One of the confounding factors related to occupational NIHL has been the complexity of differentiating contributions of age related hearing loss (ARHL). Several similarities between ARHL and NIHL make it difficult to distinguish the relative contribution of aging and noise on hearing. Firstly pure tone patterns are similar, with high frequencies affected more than low frequencies (Dobie, 1992). The mechanism of progressive pathological changes and damage to the cochlea caused by aging are also often the same factors indicated to increase a person’s susceptibility to NIHL (Pyykkö, et al., 2007; Dobie, 2008). Some studies have shown that the effect of noise on hearing is most in the early years of exposure but in later years the age related hearing loss contributes more to the total loss of hearing than NIHL (Berger, Royster & Thomas, 1978; Dobie, 2008; Pyykkö, et al., 2007). In a study by Dobie (2008) predictions were made about the burden of NIHL and ARHL in the United States (US). This author estimated that 10.5% of all hearing loss cases in the US can be attributed to NIHL. Dobie (2008) arrives at the conclusion that most, estimated to be as high as 80%, of the burden of adult-onset hearing impairment is age-related.

Because of the interaction and co-existence of ARHL and NIHL this study aimed to describe the differential effect of noise exposure and age-related hearing loss in a large sample of South Africa gold miners.

METHOD

A retrospective cohort design was followed. Approval was obtained from the relevant authorities responsible for research at the gold mine under investigation and the Ethics Committee of the University of Pretoria prior to the commencement of the study. Audiological data were accessed from the mine's electronic database (Everest) and all required information was exported into Microsoft Excel 2007 worksheets.

Participants and audiometric database

For this study the most recent audiograms of 40123 mine workers were used. Data were selected from audiometric and noise measurement records of the participants, collected between 2001 and 2008 and made available by the mine's occupational health department. Participants were categorized in terms of noise exposure, age and race. A limitation of the current study is that noise data was not available for all individuals and occupations. The classification of occupations into noise groups was undertaken by the occupational medical examiner and the noise hygienist, based on representative dosimeter data available. A noise group of participants working below surface (underground) with occupational noise exposure, ≥ 85 dB A (TWA), classified according to the South African regulations on the daily permissible dose of noise exposure (COIDA, 2001) and a group with no known occupational noise exposure, named control group, were defined for this study. Underground sources of high noise levels include rockdrills, ventilation fans, transportation equipment and explosive blasts (Hessel & Sluis-Cremer, 1987). Blasting and drilling underground differ from that on the surface, being influenced by mine geometry, openings and friction from wall roughness. As with other impulsive exposures, the cumulative effect on mine workers is unclear (McBride, 2004). The control group was matched with participants of the underground noise exposed group based on gender, race and age at the most recent audiogram test. There were 33961 participants in the underground noise exposed group and 6162 in the control group, thus a total of 40123 participants for this study. From the large underground noise exposed group a group with homogenous noise exposure, the drillers, were selected. South African goldmines define homogenous exposure groups (HEG) as groups of workers where occupational noise exposure, in terms of duration and intensity, are the same. Drillers in South African goldmines are typically exposed to occupational noise levels of between 90 and 130 dB A (TWA)(Franz & Phillips, 2001). From the large control group the administration workers, were selected and data compared to the driller group.

These noise groups were further divided into different age groups as shown in Table 1.

Table 1: Age and race distribution of the 40 123 South African mine workers in this retrospective cohort study. The cohort included the hearing threshold data of a control group with no known occupational noise exposure (n=6162) and a underground noise exposed group (occupational noise exposure of ≥ 85 dB A (TWA) (n=33961).

Age categories and race (Black (B) & White (W))	**Noise exposed and unexposed groups (n=number of participants)**	
	Underground (UG) noise group $N_{UG\ Noise\ group}$ **=33961**	**Control group** $N_{Control\ Group}$ **=6162**
16 to 30yrs	$N_{16-30yrs}$ **=7568**	$N_{16-30yrs}$ **=1623**
B	6192	1301
W	1340	303
31 to 40yrs	$N_{31-40yrs}$ **=11190**	$N_{31-40yrs}$ **=2327**
B	9739	1937
W	1361	363
41 to 50yrs	$N_{41-50yrs}$ **=11058**	$N_{41-50yrs}$ **=1696**
B	9570	1405
W	1410	267
51 to 60yrs	$N_{51-60yrs}$ **=3683**	$N_{51-60yrs}$ **=492**
B	2902	377
W	754	104
61 to 65yrs	$N_{61-65yrs}$ **=250**	$N_{61-65yrs}$ **=24**
B	154	11
W	94	12
NOTE: Numbers do not add up to the total as not all participants had race data available.		

The two largest age groups were the 31-40 years and 41-50 years with more than eleven thousand workers. The smallest age group was the 61-65 group with 250 workers in the noise group and 24 in the control group. Data received from the mines however, did not include all information for all participants (for example information about the race or age of some participants were not available). Because of the very large sample size of the cohort (from which these purposive samples were selected), numbers of participants with the relevant information were still sufficient to do statistical analyses.

Procedures

In terms of the Mine Health and Safety Act (DME, 2003), Instruction 171 (COIDA, 2001) and South Africa National Standards (SANS10083:2007, 2007) the employer is obliged to establish and maintain a system of medical surveillance for all employees in any working place where the equivalent, continuous A-weighted sound pressure level, normalized to an 8 hour working day or a 40 hour working week equals or exceeds 85 dB A. Legislation (Instruction 171) made it compulsory that a baseline audiogram is conducted for all individuals within two years after this legislation had been published and within 30 days for new employees who had not worked previously. The mine concerned in this study complied with these regulations and therefore audiograms from the year 2001 onwards until 2008 were used. The audiometric records consisted of pure-tone air-conduction audiograms for right and left ear respectively. Some audiograms were performed by the mine occupational personnel during baseline, monitoring or exit hearing screening tests. In the event of a hearing loss amounting to a shift from baseline (as per Instruction 171 Percentage Loss of Hearing (PLH) tables), diagnostic audiograms were obtained by an audiologists registered under the Health Professions Council of South Africa (COIDA, 2001).

For the purpose of this study only the most recent audiogram of each participant was used. The most recent audiograms of 40123 mine workers were therefore analyzed. Audiograms comprised the following frequencies: 0.5, 1, 2, 3, 4, 6 and 8 kHz. The audiometer used to collect data was a Tremetrics RA 600 Type 4 audiometer (serial no 971499) with TDH 39 headphones. Up to ten workers can be tested simultaneously using the audiometer's automatic testing procedure and specifically designed software (Everest). Diagnostic testing was conducted using a Type 1 Clinical Audiometer (GSI 61). Audiometry for this study was conducted in a soundproof room that complied with the relevant requirements for background noise and environmental conditions stipulated in the South African National Standards (SANS) document (SANS10154-1:2001). This standard provides background noise limits for air-conduction, bone-conduction and sound-field audiometry. Audiometry was conducted at the specific mines according to the specifications set out in Instruction 171 (COIDA, 2001).

Data analysis

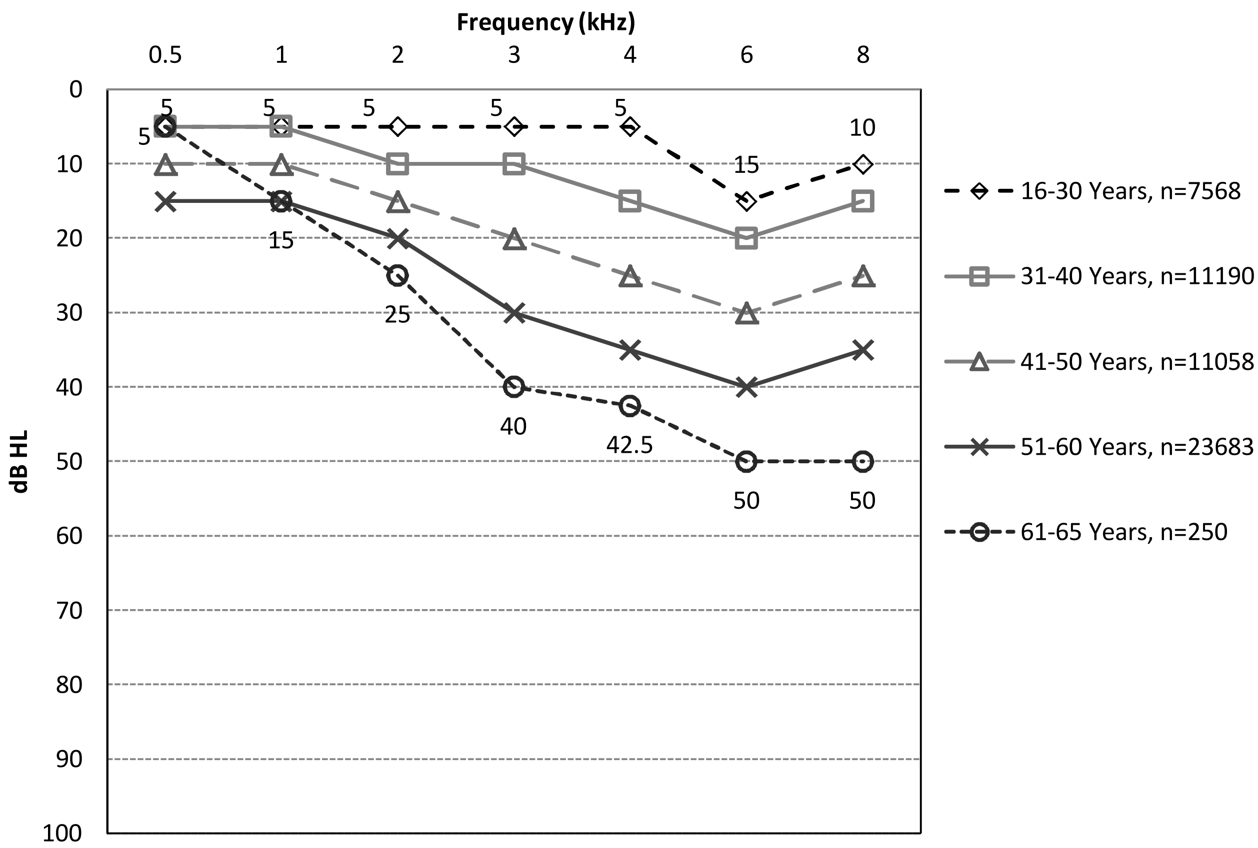
As threshold distributions of population-based samples (unlike distributions of multiple estimates for an individual) are usually positively skewed (ANSI, 1996), showing greater mean values compared to median values, audiometric frequencies were analyzed by their medians (50th percentile) and 95th percentiles. Medians and 95th percentile values were calculated using the participants' binaural averages per frequency. Medians for this study were calculated by the conventional method, where for example the median of a group of 15 would be simply the 8th-ranked value. Another method used by some of the population standards (ISO 1990:1999), used for comparisons with this study's medians, calculated the median for grouped data, assuming that the cases in each 5-dB interval are evenly distributed (Dobie, 2006). Data were analyzed per frequency, using the binaural average. Using the audiometric values (in dB HL) a binaural high frequency average (HFA346) for frequencies 3,4 and 6 kHz for each ear were calculated and also a low binaural frequency average (0.5, 1, 2 kHz) (LFA512). The reason for analyzing the lower and higher frequencies separately was to be able to make a more specific comparison between the low and high frequencies, due to the fact that noise and age have a greater influence on the higher frequencies (Sliwinska-Kowalska et al., 2006).

Analysis of covariance (ANCOVA) and pairwise comparisons were used to establish whether statistically significant relationships existed between variables. It is important to note that the large sample size resulted in small standard errors, where $t=(x1-x2)/\sqrt{(SD1/n1+SD2/n2)}$ and that these statistical differences (very small p-values) were mainly attributed to the large t-values. Although some observed differences were statistically significant, they may not be clinically relevant. In order to aid comparison with studies making use of the United States of America (ANSI S3.44-1996) standard, describing the distributions of hearing thresholds, hearing thresholds of the cohort were compared to this standard. Annex C (offering medians for different racial and gender groups) distributions represent binaural averages analyzed by their medians, 10th and 90th percentiles and age groups in 10 year intervals (e.g. 30 include 25-34 years etc.). These values were also calculated for the control and the underground noise groups and compared with ANSI S3.44 Annex C in table format.

RESULTS

Median threshold values for all frequencies progressively become more elevated as participants in the noise exposed group become older (Figure 1). This trend was also noted in the control group (table 2). The gradual decrease in hearing thresholds was

Figure 1: Comparison of median thresholds (in dBHL) by test frequency as a function of the age groups in the underground noise group (N=33,961)



most prominent for the higher frequencies. For example, differences between median thresholds of participants in the 61 to 65 age group versus the 16 to 30 age group was 0 dB at 0.5 Hz, 10 dB at 1 kHz, 20 dB at 2 kHz, 35 dB at 3 kHz, 38.5 at 4 kHz, 35 dB at 6 kHz and 40 dB at 8 kHz. Between the consecutive age groups the greatest difference between median thresholds was 10 dB at 4 kHz between those 16 to 30 and 31 to 40 years of age, 10 dB at 3, 4, 6 kHz between those 31 to 40 and 41 to 50 years of age, 10 dB at 3, 4, and 6 kHz between those 41 to 50 years and 51 to 60 years of age and 10 dB at 3 and 6 kHz between those 51 to 60 years and those 61 to 65 years of age.

Table 2: Median threshold values (in dB HL) per frequency for the control group categorised by age groups, underground noise group values shown in brackets where a difference exists between the values of the two groups (underground noise group: Underground occupational noise ≥ 85 dB A (TWA), control group: No known occupational noise)

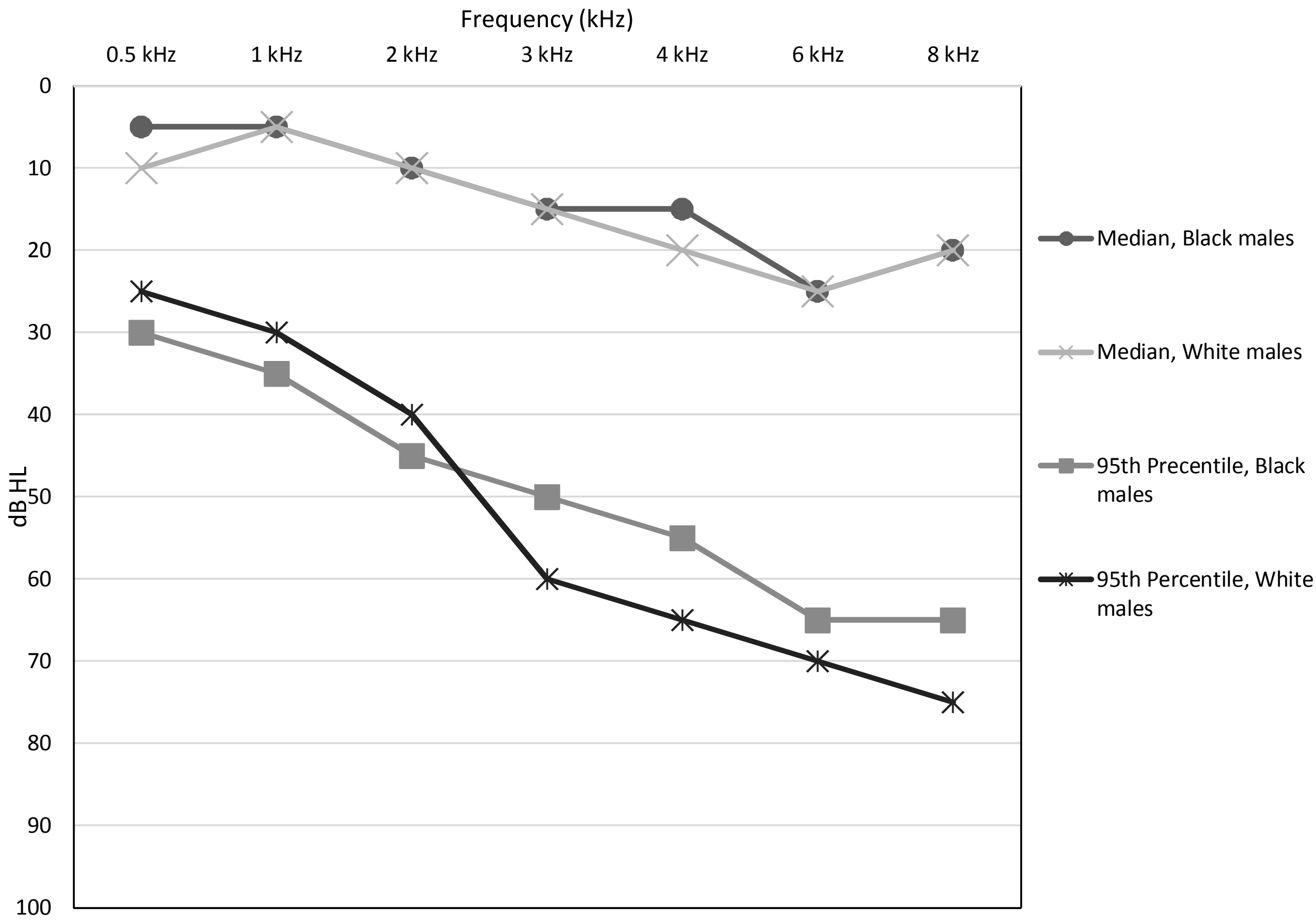
	Control group: (N=6162)						
	Median values for thresholds (dB HL) per frequency for control group (Underground noise group median thresholds in brackets, where different) Underground noise group: (N=33961)						
	0.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
16 to 30 years (n=1623)	5	5	5	5	5	15	10
31 to 40 years (n=2327)	5	5	10	10	15	20	15
41 to 50 years (n=1696)	10	10	15	20	25	30	25
51 to 60 years (n=3683)	10	15	25 (20)	30	35	35 (40)	35
61 to 65 years (n=24)	20 (5)	10	20 (25)	25 (40)	35 (42)	35 (50)	40 (50)

The median threshold values for the underground noise group compared to the control group (table 1) was largely similar. Age group differences were mostly observed for the age group 61 to 65 years. All the higher frequencies (2, 3, 4, 6 and 8 kHz) had more elevated thresholds for the underground noise group compared to the control group, with the largest differences (15 dB) observed at 3 and 6 kHz.

The underground noise group and the control group differed significantly (worse for underground noise group) with respect to the median for all frequencies after adjusting for age (ANCOVA; $p<0.01$)

In order to investigate the effect of the race on median and 95th percentile values in the underground noise exposed group these values were compared for white and black male participants (Figure 2).

Figure 2: Median and 95th Percentile values for thresholds in dB HL per frequency for participants in underground noise group categorised by race (Black Male, n=17933; White Male, n=2687)



Median thresholds showed a difference at 4 kHz with the white males' median 5 dB worse than the medians for black males (Figure 2). A difference between these two groups was also observed at 0.5 kHz with the median for black males 5 dB worse than the median for white males. When 95th percentile values of the threshold distributions were used (for the 5% with the highest thresholds) differences between the race groups (underground noise group) were more pronounced than for the median threshold values (shown in figure 2). As with the median threshold values the largest thresholds (95^{th} percentiles shown in Figure 2) were observed for white males, followed by black males. Between the 95^{th} percentiles of male groups differences of between 5 and 10 dB were noted across the frequency range. After correcting for age (ANCOVA), pair wise comparisons (F-test) indicated a significant difference between the black male group and white male group ($p<0.01$) for the low and high frequencies, with thresholds for the low frequencies (0.5, 1 and 2 kHz) significantly worse for black males and high frequencies (3, 4, 6 and 8 kHz) significantly better compared to white males.

Table 3: Median and 95th percentile values for thresholds (in dB HL) across frequency for the control group according to race. Underground noise group values included where a difference existed between the two groups (underground occupational noise ≥85 dB A TWA; the control group: No known occupational noise)

			Underground noise group: Black Male (n=17933) White Male (n=2687)			Control group: Black Male (n=2790) White Male (n=508)	
	Median values for thresholds (dB HL) per frequency for the control group (underground noise median thresholds in brackets)						
	0.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
Black Male	5	5	10	10 (15)	15	20 (25)	20
White Male	10	5	10	15	20	22.5 (25)	20
	95^{th} Percentile values for thresholds (dB HL) per frequency for the control group (Underground noise group 95^{th} Percentile values in brackets)						
	0.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
Black Male	30	35	40 (45)	50	55	60 (65)	60 (65)
White Male	25	25 (30)	40	60	70 (65)	70	70 (75)

Table 4: Median values for binaural average thresholds across the frequency range for white male participants of underground noise group and the control group, compared to ANSI S3.44 (1996) Annex C

Median values for hearing threshold dB HL- Binaural averages										
MALE, White		Control Group (Total n:464)			ANSI S3.44 (1996) Annex C			Underground Noise Group (Total n:2367)		
Age Group *	Frequency (kHz)									
		Percentiles								
		10	50	90	10	50	90	10	50	90
30	0,5	0	5	15	3	9	17	0	5	15
Control Group: n=554 Underground Noise Group: n=146	1	0	5	12,5	-1	5	13	0	5	12,5
	2	0	5	15	-4	3	14	0	5	15
	3	2,5	7,5	20	-1	6	27	0	7,5	22,5
	4	2,5	10	25	1	12	37	2,5	10	27,5
	6	5	15	32,5	4	17	43	5	15	32,5
	8	0	12,5	27,5	----	----	----	2,5	10	25
40	0,5	2,5	7,5	22,5	4	10	19	0	5	15
Control Group: n=877 Underground Noise Group: n=167	1	0	7.5	20	0	6	17	0	5	17,5
	2	2,5	10	22,5	-1	6	20	2,5	7,5	22,5
	3	2,5	12,5	35	3	12	38	5	15	37,5
	4	5	20	47,5	6	21	50	5	20	47,5
	6	10	22,5	55	10	26	58	7,5	22,5	47,5
	8	5	17,5	47,5	----	----	----	5	20	47,5
50	0,5	5	12,5	27,5	5	11	21	2,5	10	25
Control Group: n=693 Underground Noise Group: n=121	1	5	12,5	27,5	1	8	20	2,5	10	25
	2	5	15	40	1	10	29	5	12,5	35
	3	10	25	62,5	6	20	48	7,5	25	57,5
	4	12,5	32,5	65	11	30	58	12,5	32,5	60
	6	17,5	32,5	65	15	36	67	17,5	35	65
	8	15	30	67,5	----	----	----	10	30	65
60	0.5	3,75	13,75	30	6	13	24	5	12,5	25
Control Group: n=243 Underground Noise Group: n=30	1	5	12,5	46,25	2	10	24	5	12,5	30
	2	8,75	28,75	55	3	15	41	7,5	20	45
	3	16,25	50	68,75	9	31	56	15	37,5	62,5
	4	26,25	50	73,5	16	41	63	22,5	45	67,5
	6	30	57,5	76	20	47	71	25	47,5	75
	8	25	53,75	82,5	----	----	----	20	50	80

*Age is grouped in 10yr intervals, that is, '30' represents ages 25 to 34 yrs, etc.

Threshold distributions for the race groups for the control group revealed elevated threshold distributions (median and 95th percentile values) for white males compared to black males. Table 3 indicates that underground noise group medians showed some differences compared to a control group.

The combined effect of age, gender and race as variables on the hearing status of goldminers data were compared to the ANSI 3.44 (1996) tables (Annex C). Hearing thresholds of the cohort (with daily underground noise exposure ≥ 85 dB A (TWA) as well as the control group) were compared to these standards in table 4 and 5.

Thresholds medians for white participants in noise group 1(shown in Table 4) of this study are very similar compared to the ANSI S3.44 (1996) Annex C. Table 5 shows that the black participants from the underground noise group had worse hearing thresholds at 6 kHz for age group 25 to 35 years, 3, 4 and 6 kHz for age group 36 to 45 years, 2 kHz for age group 46 to 55 years and 1, 2 and 3 kHz for age group 56 to 65 years.

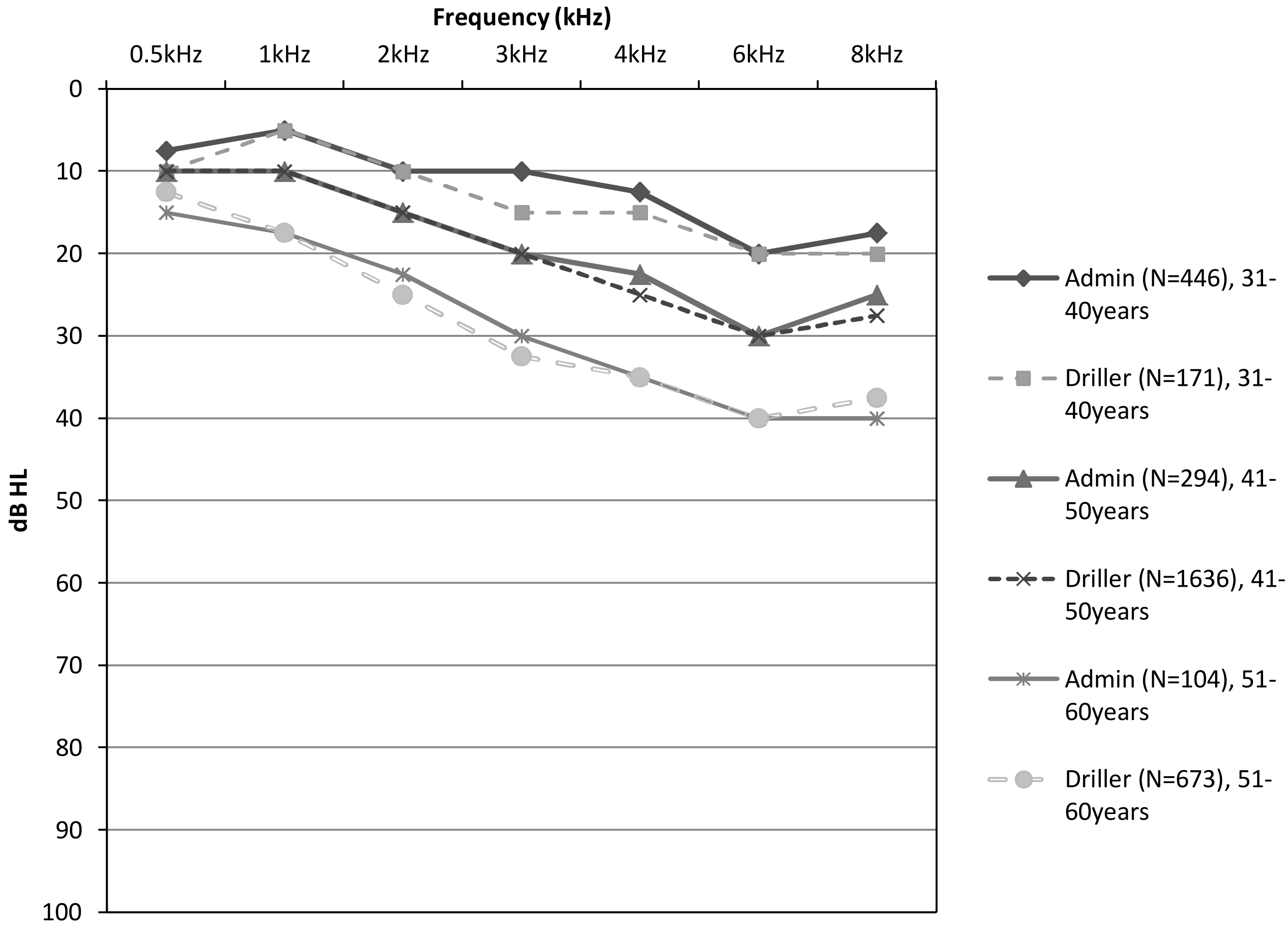
As exposure levels differ between the participants within the broader noise groups, participants were divided into groups as defined by the mine as homogeneous exposure groups (HEG) in terms of the exposure level and durations. In both the driller and administration sub groups median and 95th percentile values for thresholds across the frequency spectrum were calculated for black, male participants within the age groups 31 to 40 years, 41 to 50 years, and 51 to 60 years (Figures 3 and 4).

Table 5: Median values for binaural average thresholds across the frequency range for black male participants of underground noise group and the control group categorised by age compared to ANSI S3.44 (1996) Annex C

Median values for hearing threshold dB HL- Binaural averages										
MALE, Black		Control Group (Total n:2615)			ANSI S3.44 (1996) Annex C			Underground Noise Group (Total n:16904)		
Age Group *	Frequency (kHz)									
		Percentiles								
		10	50	90	10	50	90	10	50	90
30	0,5	0	5	17,5	-1	6	14	0	5	17,5
Control Group: n=791 Underground Noise Group: n=4133	1	0	5	15	-4	1	7	0	5	15
	2	0	7,5	20	-6	0	5	0	7,5	17,5
	3	0	7,5	20	-5	3	13	0	7,5	20
	4	2,5	7,5	25	-3	3	15	2,5	7,5	22,5
	6	5	17,5	32,5	-4	5	17	5	17,5	32,5
	8	5	12,5	32,5	----	----	----	2,5	12,5	30
40	0,5	0	7,5	20	-2	5	13	0	7,5	20
Control Group: n=1016 Underground Noise Group: n=6965	1	0	7,5	20	-4	2	9	0	7,5	22,5
	2	2,5	10	27.5	-5	1	8	2,5	10	27,5
	3	2,5	12,5	32.5	-4	5	19	2,5	12,5	35
	4	5	15	35	-3	7	22	5	17,5	37,5
	6	10	22,5	45	-3	9	25	10	22,5	45
	8	7,5	20	45	----	----	----	7,5	20	45
50	0,5	2,5	10	25	5	11	21	2,5	10	25
Control Group: n=693 Underground Noise Group: n=5000	1	2,5	10	30	1	8	20	2,5	10	32,5
	2	5	15	40	1	10	29	5	17,5	40
	3	7,5	20	45	6	20	48	7,5	22,5	47,5
	4	10	25	47,5	11	30	58	10	25	50
	6	15	30	52,5	15	36	67	15	30	55
	8	12,5	27,5	55	----	----	----	12,5	27,5	57,5
60	0,5	5	12,5	35	6	13	24	5	15	35
Control Group: n=115 Underground Noise Group: n=806	1	5	15	42,5	2	10	24	5	15	45
	2	7,5	22,5	47,5	3	15	41	7,5	25	52,5
	3	10	30	55	9	31	56	10	32,5	60
	4	15	35	60	16	41	63	15	35	62,5
	6	20	37,5	67,5	20	47	71	20	40	70
	8	17,5	37,5	67,5	----	----	----	17,5	40	70

*Age is grouped in 10yr intervals, that is, ‘30’ represents ages 25 to 34 yrs, etc.

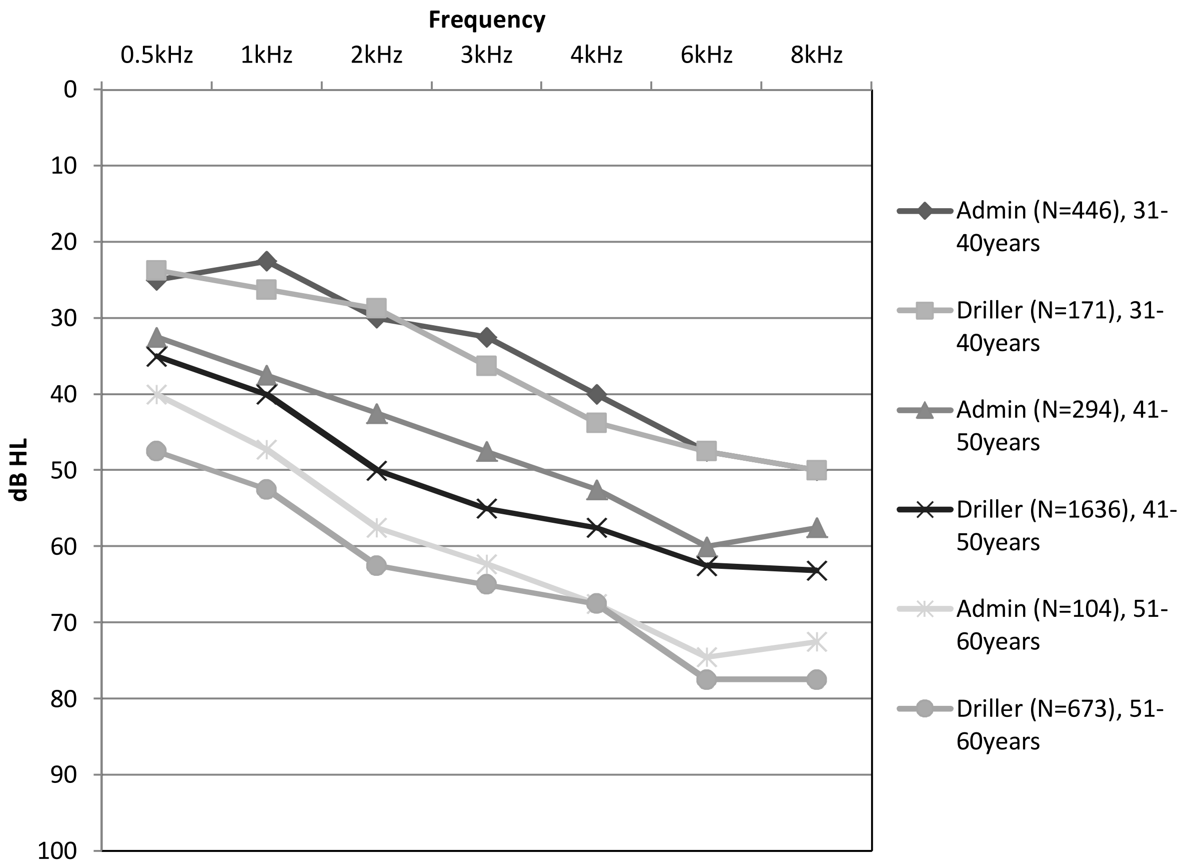
Figure 3. Comparison of median thresholds (in dB HL) for black, male participants in the driller and administration groups, for age groups 31 to 40 years, 41 to 50 years, and 51 to 60 years



The largest difference between the median values for the administration and driller groups (Figure 3) was observed in the black, male group for the age group 31 to 40 years at 3 kHz (driller group's value 5 dB more elevated than for the administration group). Differences between median threshold values for the sub groups 41 to 50 years and 51 to 60 years were less than 5 dB (not clinically significant). From figure 3 it is observable that 3 and 4 kHz showed a larger difference between the control and noise-exposed group (with control group medians better) in the earlier years compared to the later years.

Figure 4 shows the 95th percentile values for these sub groups.

Figure 4: 95th Percentile values for thresholds (in dB HL) across the frequency range for Black, Male participants in the driller and administration group, for ages 31 to 40 years, 41 to 50 years, and 51 to 60 years



The largest differences between driller and administration groups were observed for the black, male participants between 41 and 50 years at 2 and 3 kHz, with 95th percentile values for driller more than 5 dB more elevated than for the administration group (Figure 4). Based on the 95th percentile values for the black male participants in the administration and driller groups it was observed that the thresholds values of these two groups came closer in values as the frequencies became higher.

Administration and driller groups differed significantly (driller group worse results) with respect to the mean LFA512 and HFA346 after adjusting for age (ANCOVA; p values for the LFA512 was p=0.0004 and the HFA346 was p=0.069).

DISCUSSION

Hearing deteriorates over time, but the relative contributions of noise and aging to the progression of hearing loss pose a complex interaction (Dobie, 2008; Agrawal, et al., 2009; Gates, et al., 2000). Nelson et al. (2005), in their estimate of the burden of NIHL, found the peak impact of NIHL between 45 and 59 years. The reduced rate of change over time can be explained simply by the fact that hair cells lost from one cause (such as noise damage) cannot be lost again from another cause (such as age) (Gates, et al., 2000). Thus, one would expect less change over time in the thresholds of the frequency areas in the cochlea damaged by noise (Glorig, 1980). According to Nelson and colleagues (2005) the fraction of hearing loss that can be attributed to occupational hearing noise decreases as a person grows older. In the current study data significantly more participants in the noise group compared to the control group presented with hearing loss (both HFA346 and LFA 512) (Strauss et al., 2012). When considering the median thresholds, a significant difference was observed between the noise and control groups for all frequencies after adjusting for age. The largest differences between the control group and noise exposed groups were observed when the HEG groups (the drillers and administration group) were compared by their 95th percentile values. This differences (between driller and administration groups) were observed for the black, male participants between 41 and 50 years at 2 and 3 kHz, with 95th percentile values for driller 10 dB more elevated than for the administration group. Based on the 95th percentile values for the black male participants in the administration and driller groups it was observed that the differences in thresholds values for these groups became towards higher frequencies.

Although there was a statistically significant difference in proportions of participants with hearing loss between the noise exposed and the control group within the different hearing sensitivity categories, high-frequency hearing loss was also present in the control group (Strauss et al., 2012). As can be seen from the data of this study prevalence of hearing loss was greatly affected by age and the relative small difference between the noise and control groups could be evidence that hearing conservation programmes are largely effective and the use of personal hearing protection, as is mandated (COIDA 2001), may have mitigated the expected effects of noise exposure. The slightly higher prevalence of high-frequency hearing loss in the noise-exposed group, compared to the control group, however, suggests that a proportion of workers still do acquire noise-induced hearing loss. Apart from the normal effect of aging on hearing, the control group may have included persons with some previous exposure to occupational noise since information on the previous work history of participants was not available.

Race has also been described as a proxy factor for underlying systematic differences in susceptibility to NIHL or ARHL. Several studies describing hearing in normal subjects (without noise exposure) have described better hearing thresholds in black versus white subjects (Dreisbach, et al., 2007; Henselman, et al., 1995; Flamme, et al., 2011). As early as 1931 better hearing thresholds have been described in black noise-exposed subjects compared to white counterparts (Bunch & Raiford, 1931). Subsequent studies investigating the effect of race on the hearing of noise-exposed participants have found similarly that black persons have better hearing thresholds across the high frequencies (Ishii & Talbott, 1998; Henselman, et al., 1995).

Several reports on the effect of eye colour in susceptibility to NIHL (Carter, 1980; Ishii & Talbott, 1998; Carlin & McCroskey, 1980; Cunningham & Norris, 1982) indicate that individuals with blue eyes are more susceptible to noise-induced cochlear damage than are green or brown-eyed individuals which may be related to race since eye colour is highly dependent on race. This clinical research suggests that melanin, especially in the stria vasclaris of the cochlea, appears to act as a protective agent (Ishii & Talbott, 1998). Results of this study for participants of the underground noise group for the HFA346 showed significantly better hearing thresholds for black participants than for white participants across gender for medians and 95th percentiles.

Interestingly, when the LFA512 results were compared the black male participants displayed poorer 95th percentile values than white male participants. 95th Percentile values per frequency showed better hearing thresholds for black participants at 3, 4, 6 and 8 kHz. After correcting for age (ANCOVA), pairwise comparisons (F-test) indicated a significant difference between the black male group and white male group (p=0,00) for the low and high frequencies, with thresholds for the low frequencies (0.5, 1 and 2 kHz) significantly worse for black males and high frequencies (3, 4, 6 and 8 kHz) significantly better for black males compared to white males.

Comparison of these results with the ISO 1990:1999 is not possible as Annex B does not distinguish between participants based on race. ANSI S3.44 (1996) Annex C groups results for different race and gender groups and the results from this study were compared to these results (table 4 and 5). Black participants from the underground noise group showed worse hearing thresholds at 6 kHz for age group 25 to 35 years, 3, 4 and 6 kHz for age group 36 to 45 years, 2 kHz for age group 46 to 55 years and 1, 2 and 3 kHz for age group 56 to 65 years. Thresholds medians for white participants in noise group 1 of this study are very similar compared to the ANSI S3.44 (1996) Annex C.

Although it seems as if the distribution tables calculated from results of this study might be used as an alternative to other distribution tables caution must be taken when comparing these values to noise-exposed populations other than South African gold miners. The prevalence of hearing loss in the control group may be influenced by variables unique to the gold mining community in South Africa, including factors such as leisure noise, and prevalence of HIV and TB (Brits et al., 2011).

CONCLUSION

Age was the most important influence on hearing thresholds for the noise and control groups. This study included the largest published sample of black males exposed to occupational noise (N=17933). Participants from the underground noise group for the high-frequency thresholds showed significantly better hearing thresholds for black participants than for white participants for medians and 95th percentiles. Black male participants showed significantly worse low frequency thresholds than white males (underground noise group). To date this was the largest study conducted investigating the hearing thresholds of NIHL in a cohort of gold miners.

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