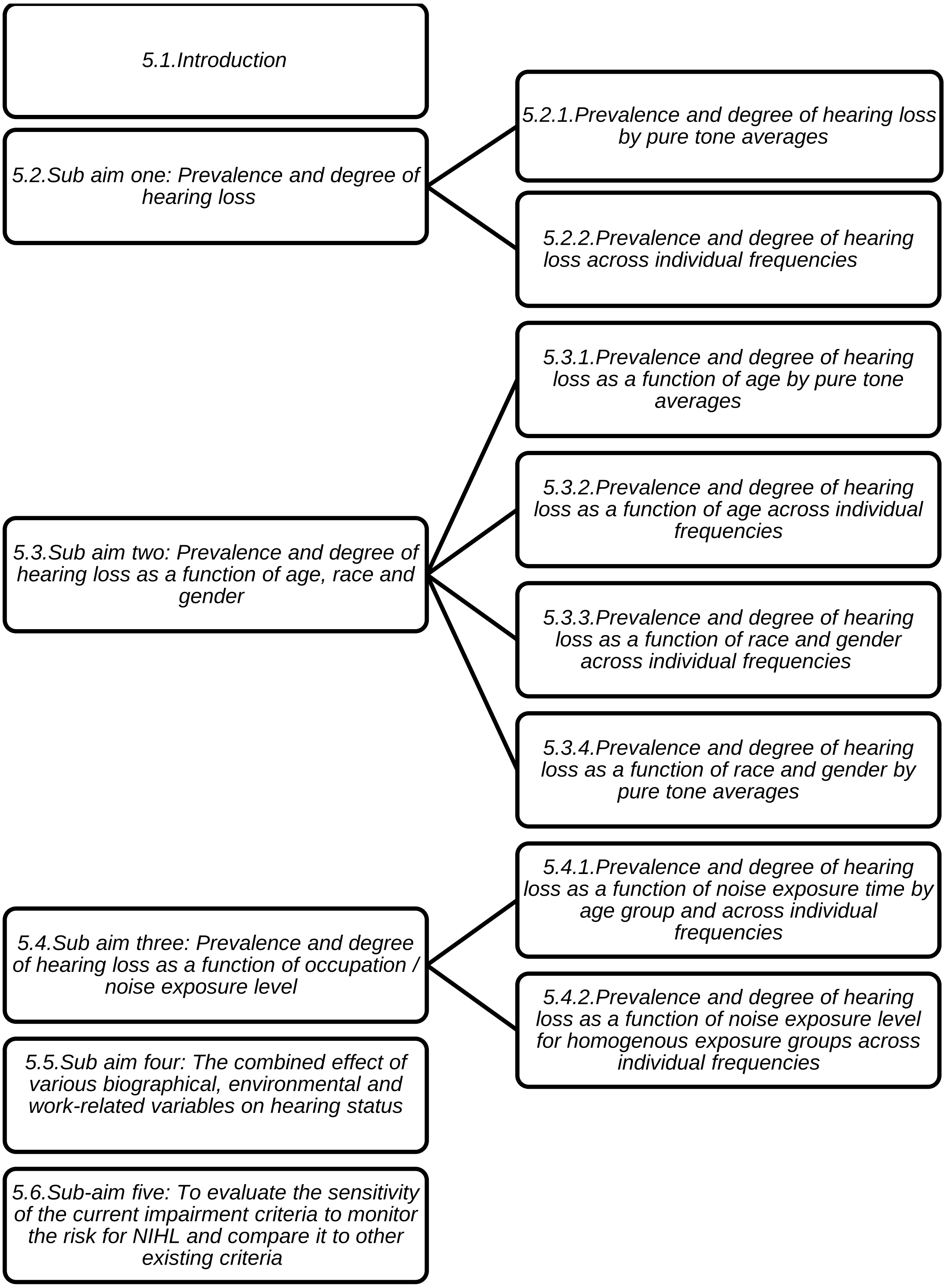
5. Results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5.1. Introduction

In this chapter the results will be discussed according to the sub aims as set out in chapters one and three. The main aim of this study was to describe the degree, prevalence, and progression of NIHL and to evaluate the criteria for determining hearing impairment in South African gold miners. To aid navigation through the results' section the following graph presents the sub aims specified to attain the main aim of the research.

Main aim:

To describe the degree, prevalence, and progression of NIHL and to evaluate the criteria for determining hearing impairment in South African gold miners

Sub aim one: To describe the prevalence and degree of hearing loss

Sub aim two: To describe the prevalence and degree of hearing loss as a function of age, race and gender

Sub aim three: To describe the prevalence and degree of hearing loss as a function of occupation / noise exposure level

Sub aim four: To assess the combined effect of various biographical, environmental and work-related variables on hearing status

Sub aim five: To evaluate the sensitivity of the current impairment criteria to identify NIHL and compare it to other existing criteria

Figure 5-1 Sub aims of this study constituting the main aim

For sub aim one, two, and three, describing prevalence and degree of NIHL in the cohort of gold miners (and within different groups, age, race, gender and noise), hearing test results were compared to accepted criteria for normal hearing as will be set out in the following paragraph. For sub aim four, to estimate the combined effect of NIHL and various biographical and environmental variables in this cohort, hearing threshold distributions will be compared to demographically matched control groups to evaluate if hearing thresholds are typical for a matched demographic group. A synthesis of reported effects culminated in the development of the ISO 1990:1999 and the nearly identical ANSI S3.44 (1996) guidelines. Hearing thresholds of the cohort (with daily noise exposure above 85 dB A) will be compared to these guidelines as well as to a control group with no known occupational noise exposure from the same cohort.

For sub aims one to three hearing status was assessed by analyses of hearing thresholds per frequency (section 5.2.2). Thresholds were also classified in categories based on degree of impairment (section 5.2.1) as proposed by Yantis (1994) and used by Picard et al. (2008) and Girard et al. (2009). NIHL is defined as a bilateral high frequency hearing loss (Picard, et al., 2008). Based on the data from this large scale study (N=53000) Picard (2012) suggests that within the context of NIHL, Yantis' low fence at 16 dB HL appears to be a sensible cut-off point to decide on the presence of some minimal degree of hearing loss. Furthermore, the distribution of their data showed only a few outliers beyond the 60 dB HL mark. As a whole, their data indicate that the Yantis classification may be a finer grain scale to represent NIHL (Picard, 2012).

The bilateral high frequency hearing loss is operationally defined as the bilateral average value of 3, 4, and 6 kHz (HFA346) and was used in calculations. In order to aid comparison average hearing thresholds at 0,5, 1 and 2 kHz, (low frequency average (LFA312)) were also calculated and used during analyses elsewhere in this section.

Hearing sensitivity categories ranged from normal (0-15 dB HL) to the largest permanent loss, labelled “severe” (>50 dB HL) according to the criteria set out by Yantis (1994). Intermediate degrees are specified in table 5.1.

Table 5-1 Hearing threshold categories based on the degree of impairment proposed by Yantis (1994) and used by Picard (2008) and Girard (2009)

Category of hearing sensitivity	Defined: ○ Per frequency/ ○ Per hearing threshold average for high frequencies (3, 4, 6 kHz) (HFA346)/ ○ Per hearing threshold average for low frequencies (0.5, 1 and 2 kHz)(LFA312)
Normal hearing	0-15 dB
Just noticeable hearing loss	16 to 30 dB
Mild hearing loss	31 to 40 dB
Moderate hearing loss	41 to 50 dB
Severe hearing loss	≥51 dB

5.2. Sub aim 1: Prevalence and degree of hearing loss

5.2.1. Prevalence and degree of hearing loss by pure tone averages

In order to describe the prevalence of hearing loss in the group of gold miners it is necessary to firstly determine whether a hearing loss was present and to see if this hearing loss can be ascribed to noise. Participants with no known exposure to occupational noise were grouped into the No Noise Group which included workers such as administrative workers and workers in the accounts' department. Participants with occupational noise exposure above 85 dB A over an 8-hour working day (classified according to the South African regulations on the daily permissible dose of noise exposure (SANS10083:2007, 2007)) and who worked underground were grouped into Noise Group 1 and included occupations such as drillers and boilermakers. Participants with known occupational noise exposure above 85 dB A over the 8-hour working day and who worked above ground (such as "boilermaker, surface") were grouped into Noise Group 2. Table 5.2 summarises the proportion of workers in the three noise-exposure groups, by category of hearing sensitivity (bilateral high frequency average (HFA346) (3, 4, 6 kHz) as well as the bilateral low frequency average (LFA312) (0.5, 1, 2 kHz)) (Yantis, 1994).

In order to aid comparison with studies making use of the ISO 1990:1999 age categories table 5.3 summarises the distribution of workers according to hearing sensitivity (bilateral HFA346), noise exposure levels and ISO 1990:1999 age categories.

Table 5-2 Distribution of workers according to hearing sensitivity (bilateral HFA346 and LFA312) and noise-exposure levels (N_{0-15} + N_{15-30} +N_{31-40} +N_{41-50} +N_{51+}=N_1/ N_3/ N_2)

Category of hearing sensitivity (dB)*	Participants grouped into different Noise Groups					
Bilateral HFA346 (3, 4, 6 kHz)	Noise Group 1 ≥85 dB A Underground		Noise Group 2 ≥85 dB A Surface		No Noise Group <85 dB A	
	N_1= 33749	100%	N_2= 7456	100%	N_3= 6162	100%
Normal hearing 0-15 dB	N_{0-15} 15388	45,5%	N_{0-15} 3668	49,1%	N_{0-15} 3297	53,5%
Just noticeable HL 16 to 30 dB	N_{15-30} 11389	33,7%	N_{15-30} 2329	31,2%	N_{15-30} 1871	30,3%
Mild HL 31 to 40 dB	N_{31-40} 3153	9,3%	N_{31-40} 660	8,8%	N_{31-40} 498	8%
Moderate HL 41 to 50 dB	N_{41-50} 1817	5,3%	N_{41-50} 396	5,3%	N_{41-50} 249	4%
Severe HL 51+dB	N_{51+} 2002	5,9%	N_{51+} 403	5,4%	N_{51+} 247	4%
Bilateral LFA512 (0,5, 1, 2 kHz)	Noise Group 1 ≥85 dB A Underground		Noise Group 2 ≥85 dB A Surface		No Noise Group <85 dB A	
	N_1= 33749	100%	N_2= 7456	100%	N_3= 6162	100%
Normal hearing 0-15 dB	N_{0-15} 25934	76,8%	N_{0-15} 5807	77%	N_{0-15} 4992	81%
Just noticeable HL 16 to 30 dB	N_{15-30} 5687	16,9%	N_{15-30} 1228	16%	N_{15-30} 903	14,7%
Mild HL 31 to 40 dB	N_{31-40} 1199	3,6%	N_{31-40} 236	3%	N_{31-40} 172	2,8%
Moderate HL 41 to 50 dB	N_{41-50} 463	1,4%	N_{41-50} 107	1%	N_{41-50} 59	1%
Severe HL 51+dB	N_{51+} 466	1,4%	N_{51+} 78	1%	N_{51+} 36	0,6%

*hearing loss (HL)

Table 5-3 Distribution of workers according to hearing sensitivity (bilateral HFA346), noise-exposure levels and ISO 1990:1999 age categories

Category of hearing sensitivity (dB)* Age group (ISO 1990:1999)	Participants grouped into different Noise Groups			
Bilateral HFA346 (3, 4, 6 kHz)	Noise Group 1 ≥85 dB A Underground Total=31105		No Noise Group <85 dB A Total=5668	
Age 25-35 years	N=8934	100%	2096	100%
Normal hearing 0-15 dB	6557	73,39	1553	74,09
Just noticeable HL 16 to 30 dB	1978	22,14	452	21,56
Mild HL 31 to 40 dB	226	2,52	59	2,81
Moderate HL 41 to 50 dB	112	1,25	12	0,57
Severe HL 51+dB	61	0,68	20	0,95
Age 36-45 years	12303	100%	2158	100%
Normal hearing 0-15 dB	4998	40,62	1074	49,76
Just noticeable HL 16 to 30 dB	5100	41,45	775	35,91
Mild HL 31 to 40 dB	1189	9,66	175	8,01
Moderate HL 41 to 50 dB	516	4,19	72	3,33
Severe HL 51+dB	500	4,06	62	2,87
Age 46-54 years	8087	100%	1196	100%
Normal hearing 0-15 dB	1415	17,49	228	19,06
Just noticeable HL 16 to 30 dB	3493	43,19	523	43,72
Mild HL 31 to 40 dB	1378	17,03	203	16,97
Moderate HL 41 to 50 dB	884	10,93	134	11,2
Severe HL 51+dB	917	11,33	108	9,03
Age 56-65 years	1781	100%	218	100%
Normal hearing 0-15 dB	131	7,35	12	5,5
Just noticeable HL 16 to 30 dB	533	29,92	70	32,11
Mild HL 31 to 40 dB	320	17,96	53	24,31
Moderate HL 41 to 50 dB	295	16,56	27	12,38
Severe HL 51+dB	502	28,18	56	25,68

*hearing loss (HL)

According to Table 5.2 the majority of participants were exposed to noise levels above 85 dB A, and were exposed to these noise level underground (Noise Group 1, N=33749), followed by workers exposed to high noise levels above ground (Noise Group 2, N=7456) and those who were not exposed to known occupational noise (No Noise Group, n=6162). Based on the bilateral LFA512 results in table 5.2 the proportions of workers displaying a hearing loss, not normal hearing, were 19% of the No Noise Group, 23% of Noise Group 2 and 23,2% of Noise Group 1. Even though the majority of participants in all the Noise Groups were still grouped into the normal hearing category based on the HFA346 results, the group proportions for workers with hearing loss were larger compared to the proportions when the results were used (46,5% of the No Noise Group, 50,9% of Noise Group 2, and 54,5% of Noise Group 1).

In all noise groups the proportion of participants in the “Just noticeable (HL 16 to 30 dB)” hearing sensitivity category was considerably higher based on the HFA346 than on the LFA512. These percentages range from 30,3% to 33,7% for the HFA346 versus 14,7% to 16,9% for the LFA512 thresholds. Based on the LFA512 as well as the HFA346 results, the proportion of workers in the normal hearing group was smallest for Noise Group 1. The No Noise Group had the highest proportion of participants in the normal hearing category (HFA346 and LFA512 results) compared to the other noise groups. Of all the Noise Groups only a small proportion revealed the HFA346 as well as the LFA512 results in the severe hearing sensitivity category. For the HFA346 results though, percentages varied from 4% to 5% versus 0,6% to 1,4% for the LFA512. Noise Group 1 had the highest proportion of participants (6%) in the severe hearing sensitivity category.

Table 5.3 shows that the largest difference in the proportion of participants with high frequency hearing loss was observed in the age group 36-45 years. In this age category 14% of the participants of the No Noise Group had high frequency hearing loss worse than 30 dB HL compared to the 18% for Noise Group 1.

In order to compare the proportions of the different Noise Groups the confidence interval for the proportion differences in each hearing sensitivity category was calculated and is shown in table 5.4. The proportions from two noise groups differ significantly when zero is excluded from the 95% CI for the difference between the proportions. The 95% CI for the differences between two proportions were determined using the normal approximation for the binomial distribution.

Table 5-4 The 95% confidence intervals (CI) for the difference of the population proportions between Noise Group 1 and No Noise Group (Table 5.4 a) and between Noise Group 2 and No Noise Group (Table 5.4 b) according to hearing sensitivity, for high frequency averages (HFA346) and low frequency averages (LFA512)

Table 5.4 a **Confidence intervals for the proportion differences between Noise Group 1 and No Noise Group ***		
High Frequency Average (3, 4, 6 kHz)		
Category of hearing sensitivity	95% CI for the difference between group proportions**	Noise group with higher proportion per category**
Normal hearing 0-15 dB	(-0,91 ; -0,64)	No Noise Group
Just noticeable HL* 16 to 30 dB	(0,02 ; 0,045)	Noise Group 1
Mild HL 31 to 40 dB	(0,004 ; 0,019)	Noise Group 1
Moderate HL 41 to 50 dB	(0,007 ; 0,018)	Noise Group 1
Severe HL 51+dB	(0,013 ; 0,024)	Noise Group 1
Low Frequency Average (0.5, 1, 2 kHz)		
Category of hearing sensitivity	95% CI for the difference between group proportions **	Noise group with higher proportion per category**
Normal hearing 0-15 dB	(-0,52 ; -0,305)	No Noise Group
Just noticeable HL 16 to 30 dB	(0,117 ; 0,031)	Noise Group 1
Mild HL 31 to 40 dB	(0,003 ; 0,012)	Noise Group 1
Moderate HL 41 to 50 dB	(0,001 ; 0,006)	Noise Group 1
Severe HL 51+dB	(0,005 ; 0,01)	Noise Group 1

*Hearing loss (HL), Noise Group 1: ≥85 dB A Underground Noise; Noise Group 2: ≥85 dB A Surface Noise; No Noise Group: no known occupational noise

** Statistical significance between proportions is attained at the 0.05 level of significance when zero is excluded from the 95% confidence interval

Table 5.4 continues on the next page

Table 5.4 b (continue)

Confidence intervals for the proportions differences between Noise Group 2 and No Noise Group *

Category of hearing sensitivity	95% CI for the difference between group proportions **	Noise group with higher proportion per category**
High Frequency Average (3, 4, 6 kHz)		
Normal hearing 0-15 dB	(-0,059 ; -0,025)	No Noise Group
Just noticeable HL 16 to 30 dB	(-0,007 ; 0,024)	No significant difference
Mild HL 31 to 40 dB	(-0,002 ; 0,016)	No significant difference
Moderate HL 41 to 50 dB	(0,005 ; 0,019)	Noise Group 2
Severe HL 51+dB	(0,007 ; 0,021)	Noise Group 2
Low Frequency Average (0,5, 1, 2 kHz)		
Category of hearing sensitivity	95% CI for the difference between group proportions **	Noise group with higher proportion per category**
Normal hearing 0-15 dB	(-0,017 ; -0,045)	No Noise Group
Just noticeable HL 16 to 30 dB	(0,005 ; 0,298)	Noise Group 2
Mild HL 31 to 40 dB	(-0,017 ; 0,009)	No significant difference
Moderate HL 41 to 50 dB	(0,001 ; 0,008)	Noise Group 2
Severe HL 51+dB	(0,004 ; 0,007)	Noise Group 2

*Hearing loss (HL), Noise Group 1: ≥85 dB A Underground Noise; Noise Group 2: ≥85 dB A Surface Noise; No Noise Group: no known occupational noise

** Statistical significance between proportions is attained at the 0,05 level of significance when zero is excluded from the 95% confidence interval

Table 5.4 summarises the CIs for the differences in proportions between Noise Group 1 (≥85 dB A Underground Noise) and the No Noise Group (in table 5.4 a) and Noise Group 2 and the No Noise Group (in table 5.4 b) for the different hearing sensitivity groups either the HFA346 or the LFA512 results. In table 5.4 a results for the HFA346 indicated that Noise Group 1 had a significantly higher proportion of participants in all the hearing-loss groups, slight, mild, moderate, and severe than the No Noise group. The proportion of participants with normal hearing was significantly more for the No Noise Group than for Noise Group 1. This was also true for the LFA512 results, where there was a significantly higher proportion of participants in Noise Group 1 in all hearing loss categories (slight, mild, moderate, and severe) than the proportion of participants in these groups for the No Noise Group; and a significantly higher proportion of participants in the normal hearing category for the No Noise Group than for Noise Group 1.

Table 5.4 b shows the differences in proportion sizes between the No Noise Group and Noise Group 2 (≥85 dB A Surface Noise). For HFA346 and LFA512 averages the No Noise Group had a significantly larger proportion of participants in the normal hearing group than those of Noise Group 2. Noise group 2 had a significantly larger proportion of participants than the No Noise Group in the following instances: HFA346 results for the moderate and severe hearing loss groups, and LFA512 results for the just noticeable, moderate, and severe hearing-loss groups.

The audiometric threshold distributions of the HFA346 and the LFA512 results (with the HFA346 indicative of noise-induced hearing loss (NIHL) were analysed by their medians (50th percentile) and 95th percentiles. The 5^{th} percentile values are not shown as all these values were 0dB HL. Table 5.4 showed a small difference between Noise Group 1 and 2 proportions. As Noise Group 2 participants had greater variability in terms of noise-exposure limits and daily-noise dosage than Noise Group 1 participants (Eloff, 2009) statistical analyses were limited to Noise Group 1 and the No Noise Group. These values derived from thresholds from participants in Noise Group 1 and the No Noise Group are demonstrated in figures 5.2, 5.3 and 5.4.

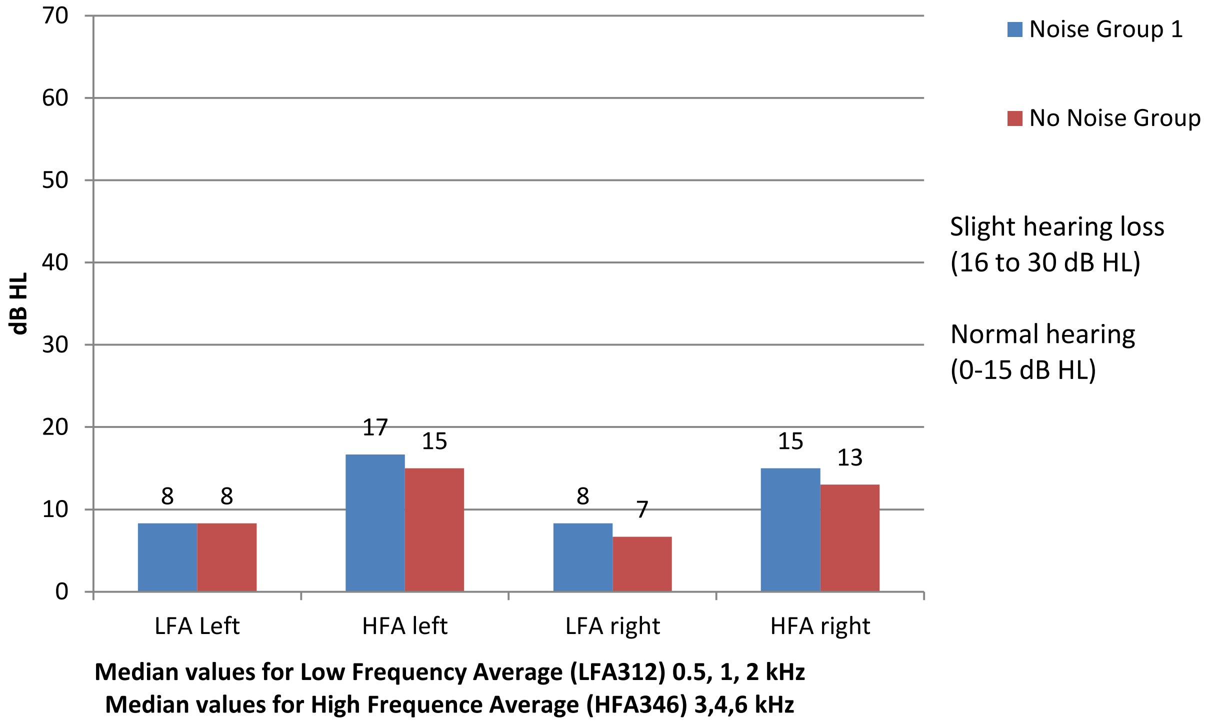


Figure 5-2 Median values for the HFA346 and the LFA512 for Noise Group 1 and No Noise Group (Noise Group 1: Underground occupational noise ≥85 dB A TWA (n= 33961); No Noise Group: No known occupational noise (n=6194))

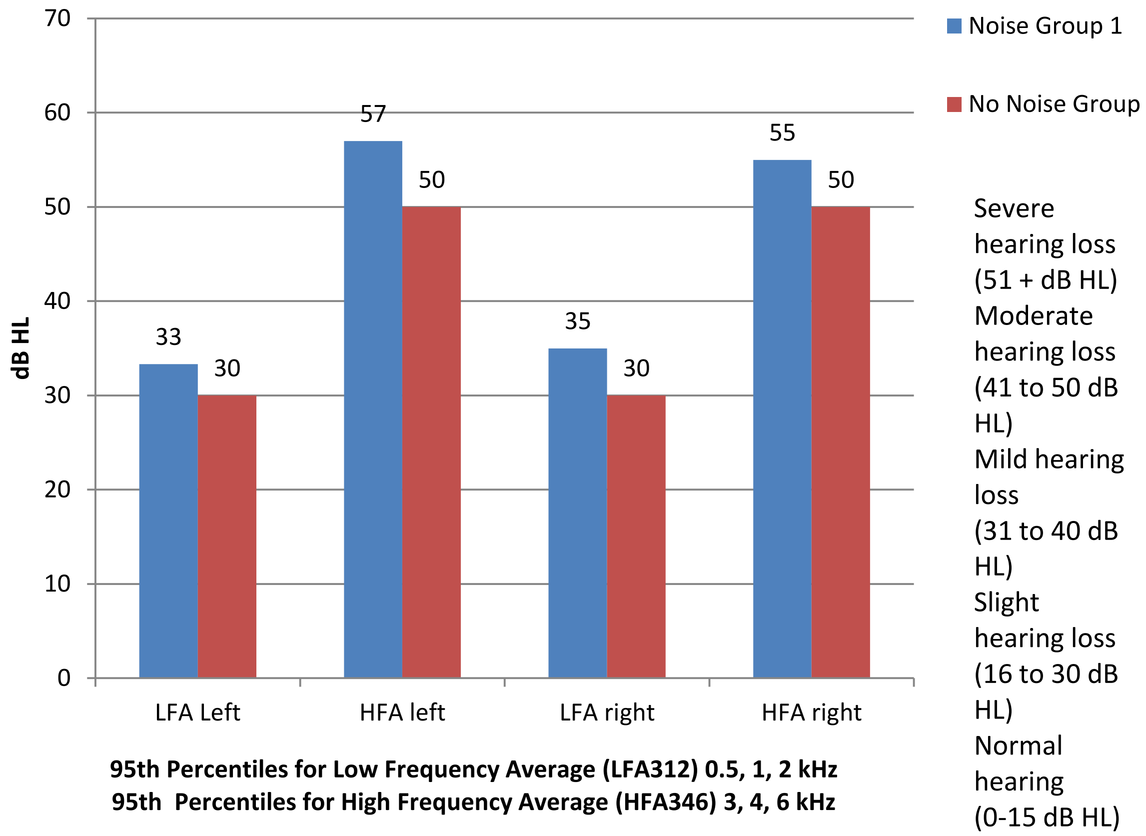


Figure 5-3 95th Percentile values for the HFA346 and the LFA512 for Noise Group 1 and No Noise Group (Noise Group 1: Underground occupational noise ≥85 dB A TWA n= 33961; No Noise Group: No known occupational noise n=6194)

All the results (shown in figures 5.2 and 5.3) show larger values, medians and 95th percentile values, for Noise Group 1 than for the No Noise Group. Both graphs show elevated thresholds where high frequencies (3, 4 and 6 kHz) were used for analyses (HFA346) compared to the low frequency averages (LFA512; 0,5, 1 and 2 kHz). All the values, median and 95th percentile, for left ear thresholds are slightly elevated compared to those of the right ears. The largest difference (with clinical significance) was seen between the 95th percentile values derived from the HFA346 for the left ears for Noise Group 1 and the No Noise Group (Noise Group 1 had a HFA346 of 57 dB HL and the No Noise Group had a HFA346 of 50 dB HL).

In an ANCOVA Noise Group 1 and the No Noise group differed significantly with respect to mean LFA512 (p=0,0001; 11,65dB versus 11,03dB) and mean HFA346 (p=0,0072; 11,45dB versus 10,81dB) after adjusting for age (Noise Group 1 more elevated than No Noise Group). However, although statistically significant this difference is clinically insignificant.

Figure 5.2 further reveals that the median HFA346 values for Noise Group 1 fell within the “slight hearing loss” category (16 to 30 dB HL). Median values for the No Noise Group (HFA346, left and right ears) revealed threshold values within the “normal hearing” category (0-15 dB HL). The 95th percentile values for participants in Noise Group 1 (HFA346 thresholds for left and right ears) fell within the “severe hearing loss” category (51+ dB HL) compared to these results for the No Noise Group participants that fell within the “moderate hearing loss” category (41 to 50 dB HL).

Bilateral LFA512 and HFA346 values (median and 95th percentile) for Noise Group 1 and the No Noise Group are shown in figure 5.4 categorised according to the hearing sensitivity groups.

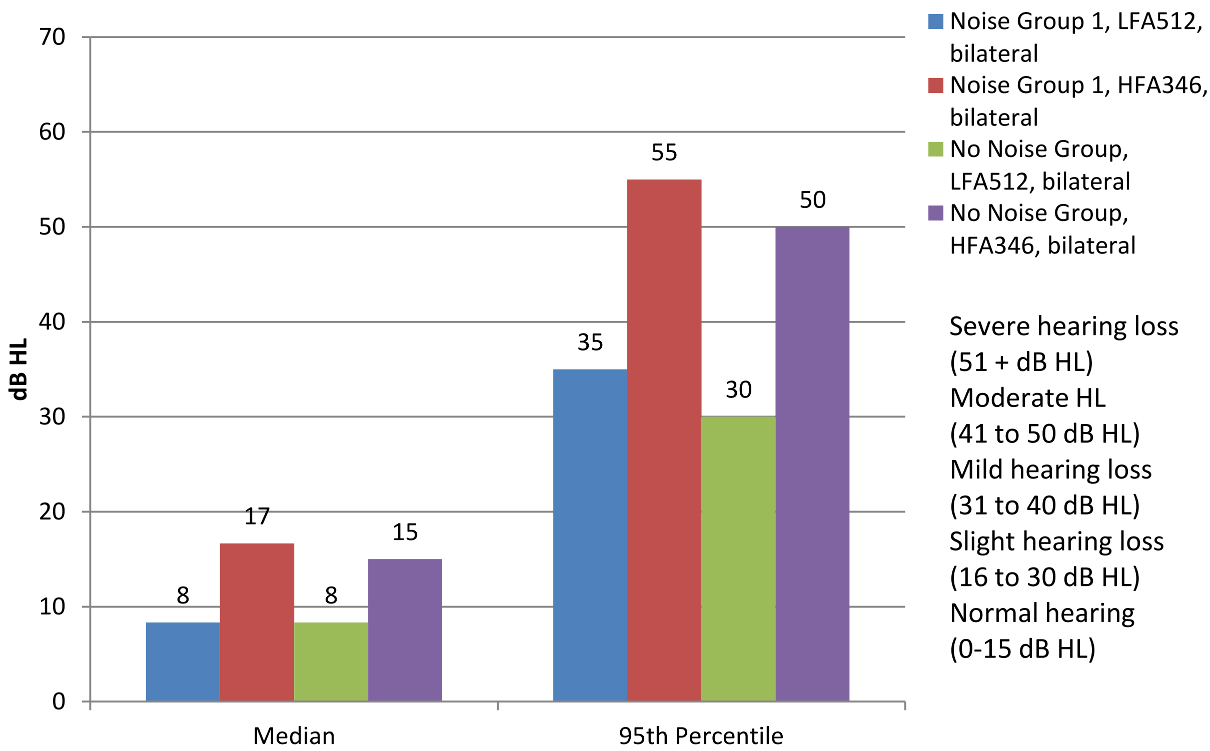


Figure 5-4 Median and 95th Percentile values for the pure tone average (PTA512) and high frequency average (HFA346) of participants in Noise Group 1 and No Noise Group (Noise Group 1: Underground occupational noise ≥85 dB A TWA , n= 33961; No Noise Group: Occupational noise <85 dB A, n=6194)

Results shown in figure 5.4 reveal that the HFA346 for thresholds are more elevated than the LFA512 for the hearing thresholds in all instances. Results revealed that median values for the two noise groups are at least 9 dB better for the LFA512 than for the HFA346 values. 95th percentile values for the LFA512 and the HFA346 results were 20dB more elevated for the HFA346 values for both noise groups. As in figure 5.2 and 5.3 the results for Noise Group 1 showed more elevated dB values, medians and 95th percentile, for all calculations, apart from the median values for the LFA512, for Noise Group 1 than for Group 3. The median values for the LFA512 for Noise Group 1 and the No Noise Group, and the median for the No Noise Group the HFA346 fell within normal limits. All other values revealed a degree of hearing loss.

5.2.2. Prevalence and degree of hearing loss across individual frequencies

In the previous section (section 5.2.1) it has been shown through analysis of the results that a larger proportion of the noise-exposed groups had elevated hearing thresholds for low frequency and high frequency averages. In this section the hearing levels will be explored further by describing thresholds for the noise-exposed and control groups across individual frequencies. 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, the audiometric threshold distributions were analysed by their medians (50th percentile) and 95th percentiles (all the 5th percentiles were 0 dB HL).

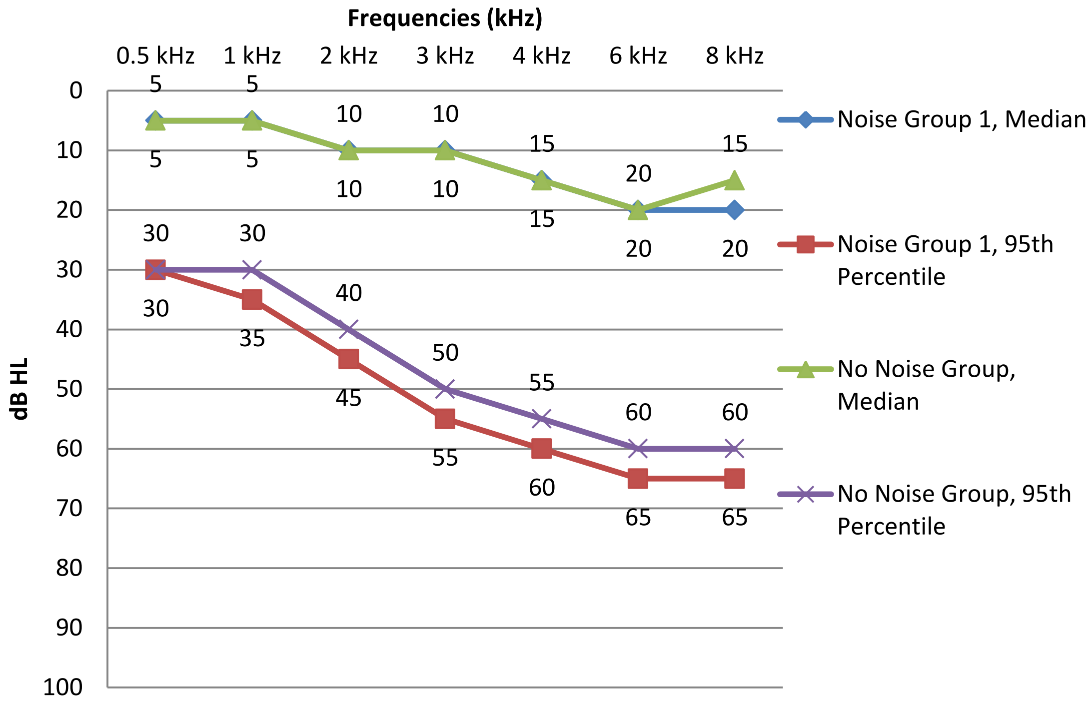


Figure 5-5 Left ear, medians and 95th percentile threshold values (dB HL) per frequency (Noise Group 1: Underground occupational noise ≥85 dB A (TWA), n= 33961; No Noise Group: No known occupational noise, n=6194)

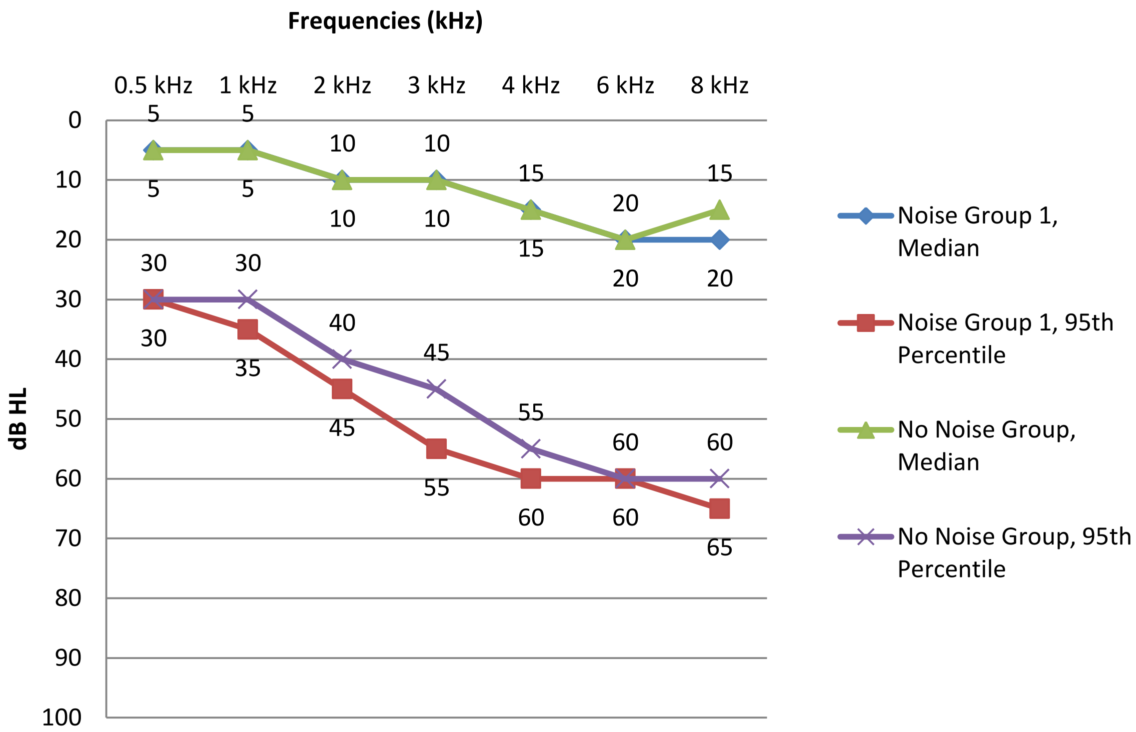


Figure 5-6 Right ear, medians and 95 percentile threshold values (dB HL) per frequency. Noise Group 1: Underground occupational noise ≥85 dB A TWA (n= 33961) No Noise Group: No known occupational noise (n=6194)

From figures 5.5 and 5.6 data for the left and right ears are identical except for the 95th percentile value for the No Noise Group that is 5 dB better for the right ear than for the left ear (45 dB HL). For Noise Group 1 and the No Noise Group the median values are identical for both ears for all frequencies except 8 kHz, where the No Noise Group shows 5 dB better median thresholds than the values for Noise Group 1. Through comparison between the threshold values for the two groups in the 95th percentile, it is demonstrated that the non-exposed group (No Noise Group) showed at least 5 dB better values over the whole frequency range (figure 5.5). Based on the notch criteria of Coles and colleagues (Coles, Lutman, & Buffin, 2000), defined as a high-frequency notch where the hearing threshold at 3, 4, and/or 6 kHz is at least 10 dB greater than at 1or 2 kHz and at least 10 dB greater than at 6 or 8 kHz, the greatest notch was observed in both groups at 6 kHz (15 dB notch).

5.3. Sub aim 2: Prevalence and degree of hearing loss as a function of age, race and gender

5.3.1. Prevalence and degree of hearing loss as a function of age by pure tone averages

To describe the prevalence of hearing loss in the group of gold miners the participants were divided into two different noise groups, namely the No Noise Group (no known occupational noise exposure) and Noise Group 1 (underground occupational noise exposure of ≥ 85 dB A). These participants were then further divided into different age groups. For the purposes of comparison these age groups were categorised as follows: 16 to 30 years, 31 to 40 years, 41 to 50 years, 51 to 60 years, and 61 to 65 years. Within these age categories the participants were divided based on the HFA346 and the LFA512 of their hearing thresholds into the different hearing sensitivity categories (Yantis, 1994) as described in section 5.2. The following tables show the numbers of participants in each of the age categories for Noise Group 1 and the No Noise Group.

Table 5-5 Breakdown of numbers (n) of participants (with percentage of sample indicated) categorised in the different Noise Groups and different age categories used for calculations of proportion of the different hearing sensitivity categories (shown in figures 5.7 and 5.8)

	16 to 30 Years	31 to 40 Years	41 to 50 Years	51 to 60 Years	61 to 65 Years	Total n
Noise Group 1	7568 22.3 %	11190 32.9%	11058 32.6%	3683 10.9%	250 0.8%	33961 100%
No Noise Group	1623 26.4%	2327 37.8%	1696 27.4%	492 7,9%	24 0.4%	6194 100%

From this table it is clear that sample sizes are large (with exception of the age group 61to 65 years). In figures 5.7 and 5.8 the percentage of participants in these different categories are shown as a proportion of the hearing sensitivity category. These calculations are based on the LFA512 thresholds and the HFA346 thresholds.

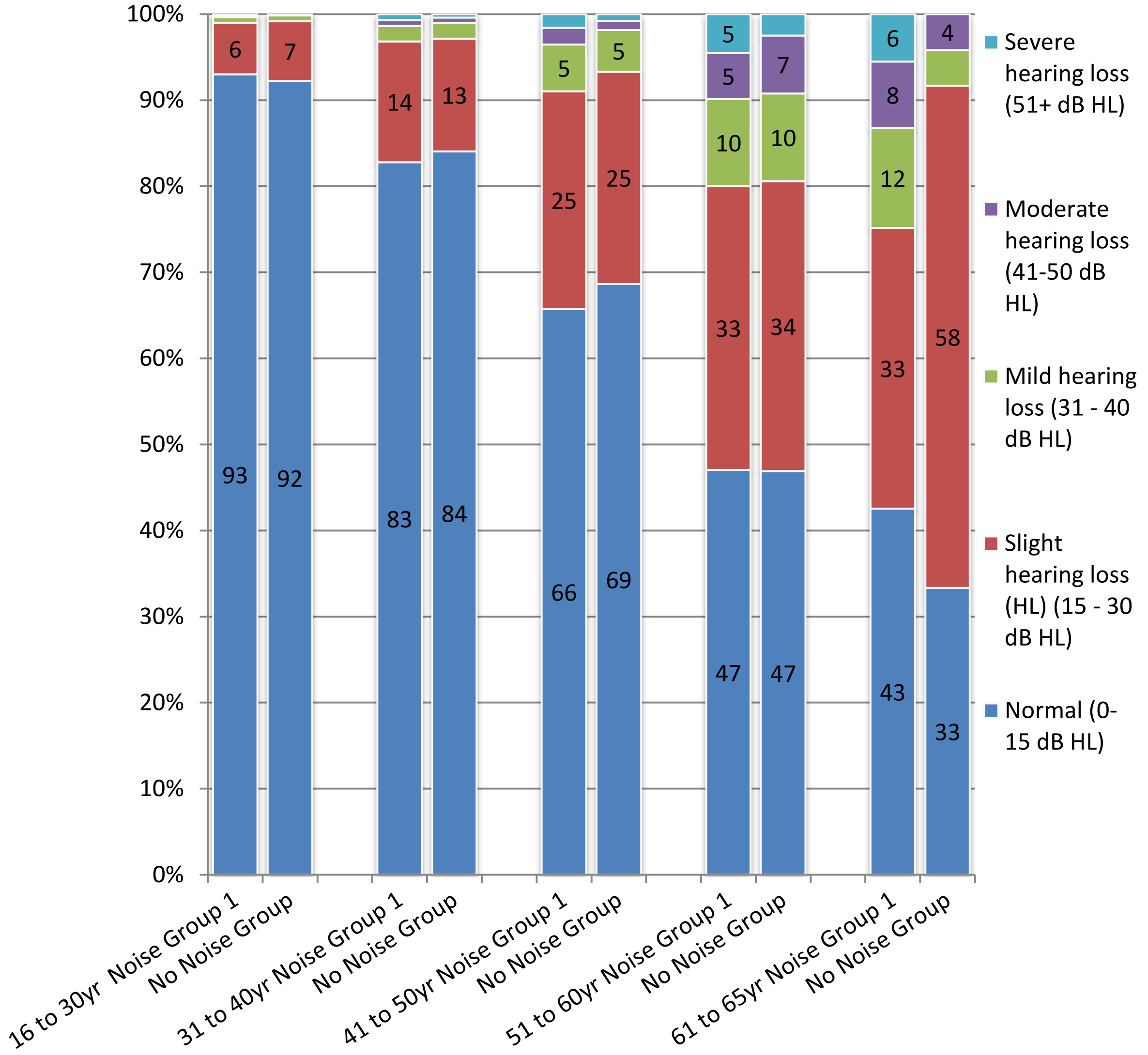


Figure 5-7 Percentage of participants in Noise Group 1 and the No Noise Group per age group across the hearing-sensitivity category for the Low Frequency Averages (LFA512)

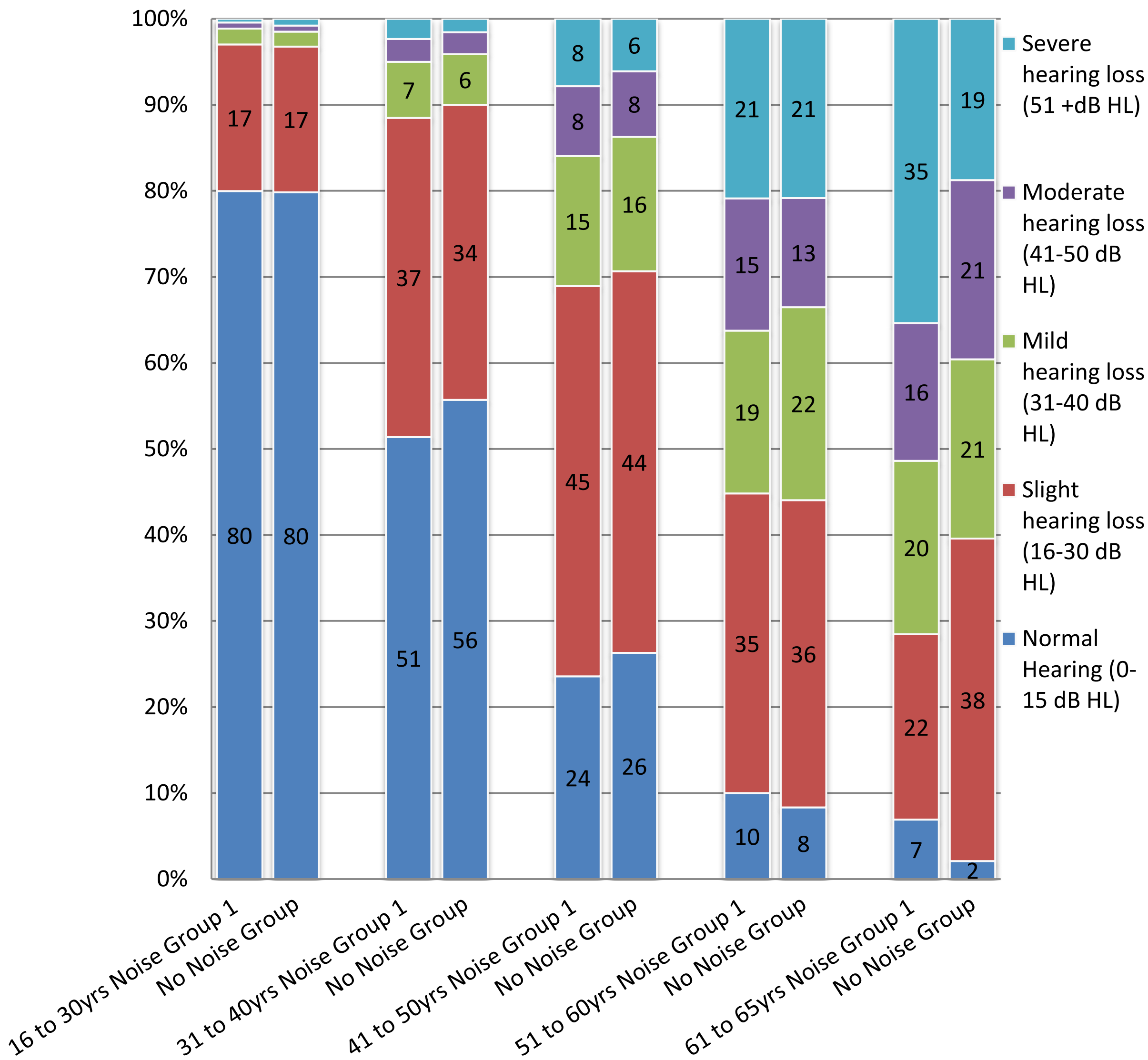


Figure 5-8 Percentage of participants in Noise Group 1 and the No Noise Group per age group per hearing sensitivity category for the High Frequency Averages (HFA512)

From figure 5.7 and 5.8 it is clear that the LFA512 results (figure 5.7) indicated a higher proportion of participants in all age groups in the normal hearing category compared to the proportion of participants in the normal category for the HFA346 results (figure 5.8). Figure 5.8, proportions based on the LFA512 results, show only a small proportion of participants in the mild to severe hearing sensitivity categories and only in the age groups 51 to 60 years and 61 to65 years. The largest differences between proportions of Noise Group 1 and the No Noise Group (in the different hearing sensitivity categories) were observed when the HFA346 of hearing thresholds were used.

Results shown in figure 5.8 reveal that the largest proportion of participants in the age group 16 to 30 years had HFA346 values within the normal hearing category (80% for Noise Group 1 and the No Noise Group). Virtually none of the participants in this age group had the HFA346 results within the mild-severe hearing-sensitivity category. Results for this age group are similar for Noise Group 1 and the No Noise Group. In the age group 31 to 40 years (HFA346 results) the largest proportion for both Noise Groups fell within the normal hearing group (51% Noise Group 1 and 56% No Noise Group) followed by the slight hearing-loss category. For both Noise Groups a small proportion of the participants between 31 and 40 years revealed hearing loss in the mild to severe hearing-loss categories (11% Noise Group 1 and 10% No Noise Group). For participants between 41 and 50 years (both Noise Groups) the largest proportion had the HFA346 thresholds between 16 to 30 dB HL (slight hearing-loss category). The majority of participants in the 51 to 60 years age group (for both Noise Groups) fell within the mild-severe hearing-loss categories (a slightly higher proportion for Noise Group 1 than the No Noise Group, 55% versus 56%). The largest difference between the proportions sizes of the different Noise Groups was observed for the severe hearing-loss category in the 61 to 65 years age group. 35% of participants in this age group had the HFA346 thresholds in the severe hearing-loss group compared to the 19% of the same age in the No Noise Group.

5.3.2. Prevalence and degree of hearing loss as a function of age across individual frequencies

In the previous section hearing loss of participants in the different age groups were described in terms of the hearing-loss categories. Bilateral median thresholds (per participant) were calculated per frequency for each age group for participants in Noise Group 1 and are shown in figure 5.9. Since results were very similar for the No Noise Group, results for this group were not shown in a figure but were compared to that of Noise Group 1 in table 5.6.

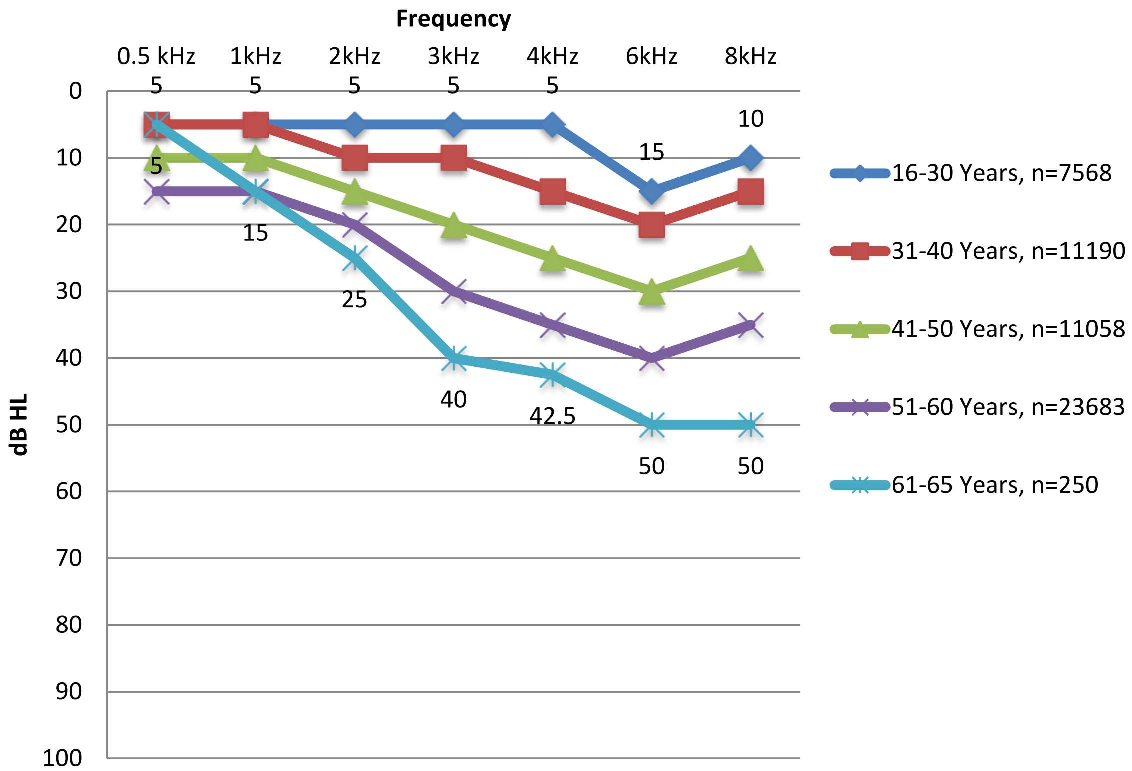


Figure 5-9 Median thresholds (in dB HL) per frequency for each age category for Noise Group 1 (N=33961)

Figure 5.9 demonstrates clearly how the median threshold values across all frequencies calculated for the different age groups for participants in Noise Group 1 became progressively more elevated as the participants' ages increased. This tendency was also seen in the results for the No Noise Group and is shown in comparison to Noise Group 1 in table 5.6. This increase in hearing thresholds grew with higher frequencies. For example, the difference between the median thresholds of the participants in the 61 to 65 age group versus the 16 to 30 age group were 0 dB at 0.5 Hz, 10 dB at 1 kHz (elevated values for the older age group at all frequencies), 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.

Based on the notch criteria of Coles and colleagues (Coles, Lutman, & Buffin, 2000), defined as a high-frequency notch where the hearing threshold at 3, 4, and/or 6 kHz is at least 10 dB greater than at 1or 2 kHz and at least 10 dB greater than at 6 or 8 kHz, a notch was observed in all average age groups except the 61 to65 year group at 6 kHz (10 dB notch). Between the consecutive age groups the greatest difference was 10 dB at 4 kHz between the 16 to 30 years and the 31 to 40 years group, 10 dB at 3,4,6 kHz between the 31 to 40 years and the 41 to 50 years groups, 10 dB at 3,4, and 6 kHz between the 41 to 50 years and the 51 to 60 years group and 10 dB at 3 and 6 kHz between the 51 to 60 years and the 61 to 65 years groups.

In order to compare the median thresholds (bilateral) of the different age groups for Noise Group 1 versus the No Noise Group these medians were tabled in table 5.6. Median thresholds values for the No Noise Group participants for the different age groups are indicated. Where these thresholds differed from those of Noise Group 1, the Noise Group 1 median values are indicated.

Table 5-6 Median threshold values (in dB HL) per frequency for the No Noise Group categorised by age groups, Noise Group 1 values show where a difference exists between the values of the two groups (Noise Group 1: Underground occupational noise ≥ 85 dB A TWA , No Noise Group: No known occupational noise)

	Noise Group 1: (N=33961)	No Noise Group: (N=6194)
No Noise Group values < Noise Group 1 values	16 to 30 years, n=7568	16 to 30 years, n=1623
	31 to 40 years, n=11190	31 to 40 years, n=2327
No Noise Group values > Noise Group 1 values	41 to 50 years, n=11058	41 to 50 years, n=1696
	51 to 60 years, n=3683	51 to 60 years, n=492
	61 to 65 years, n=250	61 to 65 years, n=24

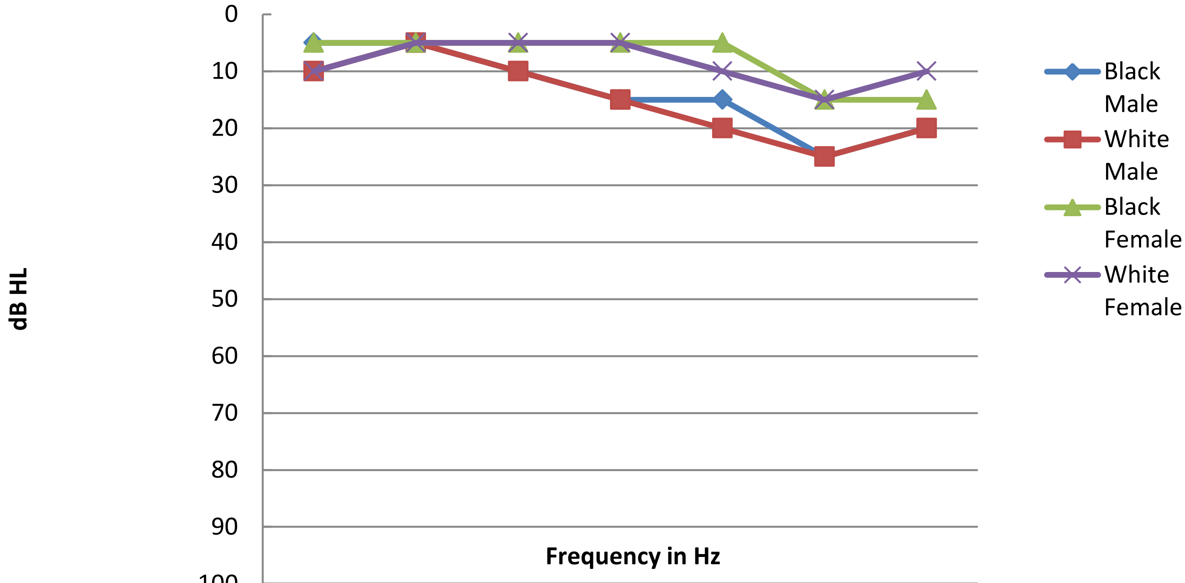
	Median values for thresholds (dB HL) per frequency for No Noise Group (Noise Group 1 median thresholds in brackets)						
	0.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
16 to 30 years	5	5	5	5	5	15	10
31 to 40 years	5	5	10	10	15	20	15
41 to 50 years	10	10	15	20	25	30	25
51 to 60 years	10	15	25 (20)	30	35	35 (40)	35
61 to 65 years	20 (5)	10	20 (25)	25 (40)	35 (42)	35 (50)	40 (50)

Table 5.6 shows that the median threshold values for Noise Group 1 versus the No Noise Group participants are very similar. The age group where differences were mostly observed was the age group 61 to 65 years. All the higher frequencies (2, 3, 4, 6 and 8 kHz) had higher values for Noise Group 1 than for the No Noise Group (with the largest differences (15 dB) observed at 3 and 6 kHz.

Noise Group 1 and the No Noise Group differed significantly (worse for Noise Group 1) with respect to the median for all frequencies in an ANCOVA after adjusting for age. All p-values were less than 0.01. (0,5kHz, p=0,0013; 1kHz, p=0,000; 2kHz, p=0,000; 3kHz, p=0,000; 4kHz, p=0,000; 6kHz, p=0,000; 8kHz, p=0,001).

5.3.3. Prevalence and degree of hearing loss as a function of race and gender across individual frequencies

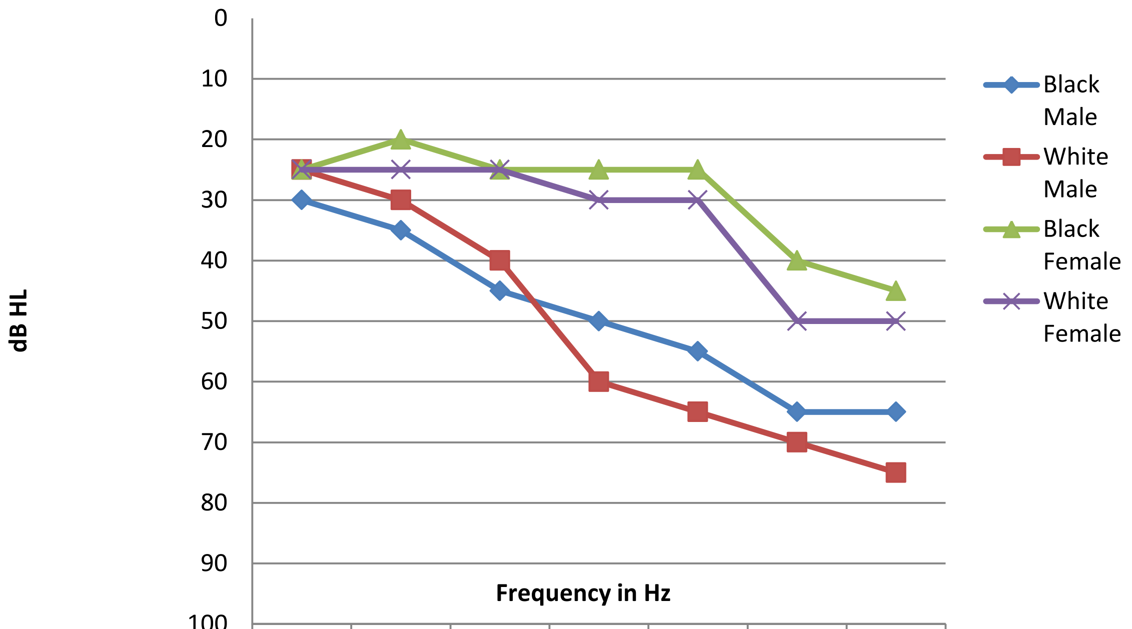
In order to describe the prevalence of hearing loss and the degree thereof as a function of race and gender, the cohort of gold miners were categorised into the following categories: black male, white male, black female and white female. For the different groups, dichotomised into Noise Group 1 and the No Noise Group, median and 95^{th} percentile values for the thresholds per frequency were calculated. Figure 5.10 shows the median threshold values for the different race and gender groups for Noise Group 1 (occupational noise exposure ≥ 85 dB A, TWA). Figure 5.11 demonstrates the 95^{th} percentile values for these thresholds. Table 5.6 aids comparison between the median and 95^{th} percentile threshold values for participants in these race and gender groups between Noise Group 1 and the No Noise Group (no known occupational noise exposure).



	0.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
Black Male	5	5	10	15	15	25	20
White Male	10	5	10	15	20	25	20
Black Female	5	5	5	5	5	15	15
White Female	10	5	5	5	10	15	10

Figure 5-10 Median values for thresholds in dB HL per frequency for participants in Noise Group 1 categorised by race and gender (Black Male, n=35866; White Male, n=5374; Black Female, n=1698; White Female, n=434)

As demonstrated by figure 5.10, the largest differences were observed between the male and female groups, especially in the high frequencies. A 10 dB difference was observed between the median thresholds for the male versus female groups at 3, 6 and 8 kHz and 20 dB at 4 kHz. The largest difference between the “best” median threshold (black female) and the most elevated median thresholds (white male) were observed at 4 kHz, a difference of 15 dB HL (white male, 20 dB HL versus black female, 5 dB HL). The median thresholds for the females were grouped close together, with the only difference between white and black females at 0.5, 4 and 8 kHz, 5 dB being more elevated for the white females in all instances. The median thresholds for men (black and white) were also grouped close together. White males showed 5 dB higher thresholds than the black males at 5 and 4 kHz.



	0.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	6 kHz	8 kHz
Black Male	30	35	45	50	55	65	65
White Male	25	30	40	60	65	70	75
Black Female	25	20	25	25	25	40	45
White Female	25	25	25	30	30	50	50

Figure 5-11 95th Percentile values for thresholds in dB HL per frequency for participants in Noise Group 1 categorised by race and gender (Black Male, n=17933; White Male, n=; Black 2687Female, n=849; White Female, n=217)

When 95th percentile values of the threshold distributions were used (for the 5% with the highest thresholds) differences between the different gender and race groups (Noise Group 1) were more pronounced than for the median threshold values (shown in figures 5.10 and 5.11). As with the median threshold values the largest thresholds (95th percentiles shown in figure 5.11) were observed for white males, followed by black males, white females and black females (best thresholds). The largest difference was measured at 4 kHz between the white males (65 dB HL) and the black females (25 dB HL). 95th Percentiles for the females showed a difference of between 5 and 10dB between the white and black females (black females had the better thresholds). Between the male groups 95th percentiles also differed between 5 and 10 dB across the frequency range. Larger differences up to 40dB were observed between the male and female groups, with the female thresholds lower than those of the male groups. After correcting for age through ANCOVA, pair wise 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.

Threshold distributions for the same race and gender groups for the No Noise Group revealed the same tendency for males to have elevated thresholds compared to females. This was also evident for white males having elevated threshold distributions (median and 95th percentile values) compared to black males in the same way as for white females and black females. To aid comparison between the two noise groups table 5.7 summarises these differences.

Table 5-7 Median and 95th percentile values for thresholds (in dB HL) across frequency for the No Noise Group according to gender and race. Noise Group 1 values were included when a difference existed between the two groups (*Noise Group 1: Underground occupational noise ≥85 dB A TWA; the No Noise Group: No known occupational noise)*

Noise Group 3 values < Noise Group 1 values Noise Group 3 values > Noise Group 1 values	Noise Group 1: Black Male (n=17933) White Male (n=2687) Black Female (n=894) White Female (n=217)			No Noise Group: Black Male (n=2790) White Male (n=508) Black Female (n=314) White Female (n=42)			
	Median values for thresholds (dB HL) per frequency for the No Noise Group (Noise Group 1 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
Black Female	5	5	5	5	5	15	15
White Female	5 (10)	5	5	5	5	15	10
	95th Percentile values for thresholds (dB HL) per frequency for the No Noise Group (Noise Group 1 95th 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)
Black Female	25	20	25	25	25	40	50 (45)
White Female	20(25)	20 (25)	25	25 (30)	30	50	35 (50)

From table 5.7 it is clear that all differences observed between the different noise groups revealed elevated thresholds for Noise Group 1 compared to the No Noise Group, apart from the 95th percentile value for white males, Noise Group 1, white male; 65 dB HL versus the No Noise Group, white male; 70 dB HL. Other differences in median threshold distributions were observed between the black and white male groups of Noise Group 1 and the No Noise Group at 6 kHz. The only thresholds that differed for all race and gender groups at a selected frequency were the 95th percentile values at 8 kHz, with the largest difference, Noise Group 1 15 dB higher than for the No Noise Group, observed for the white female group.

5.3.4. Prevalence and degree of hearing loss as a function of race and gender by pure tone averages

The high and low frequency averages (HFA346 and the LFA512) of the thresholds of the different race and gender groups were compared in terms of median and 95th percentile values for these groups (figures 5.12 and 5.13).

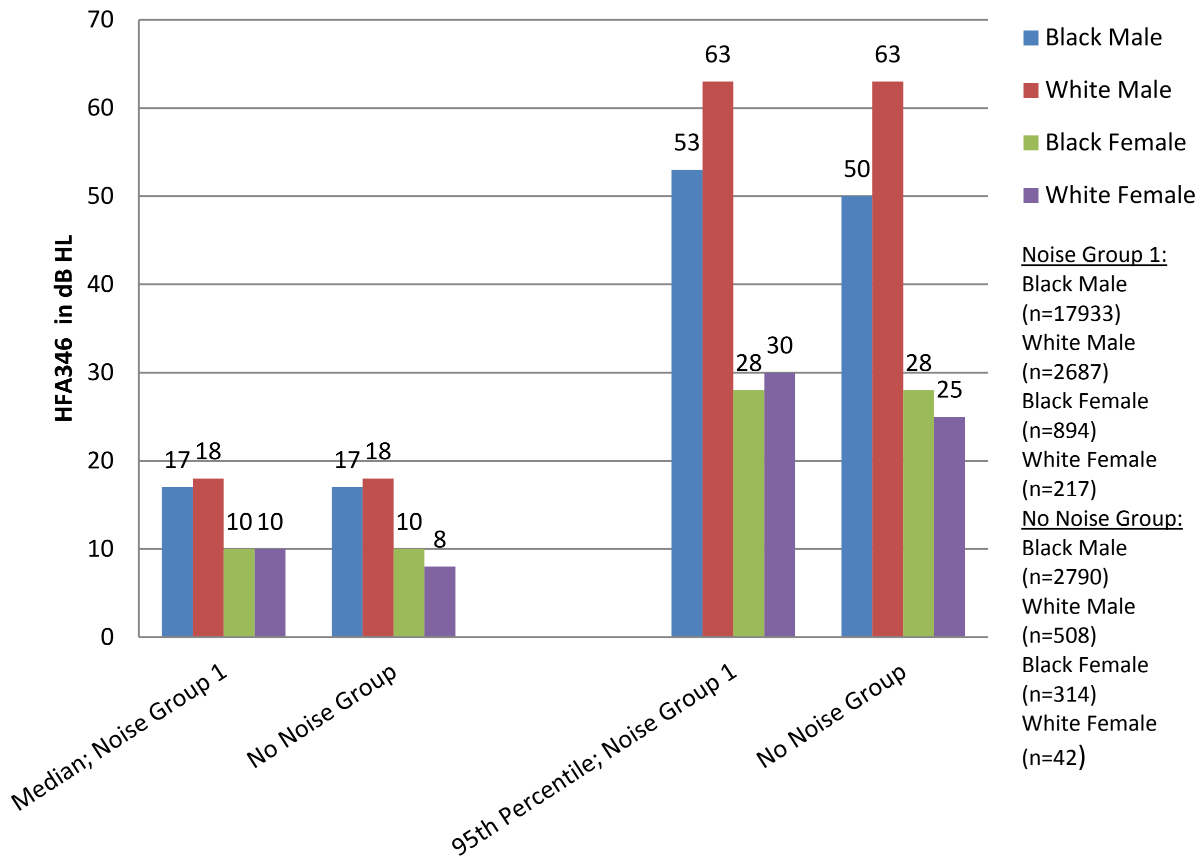


Figure 5-12 Median and 95th percentile values of the high frequency average for thresholds at 3, 4, and 6 kHz, (HFA346) compared for the different race and gender groups within the different Noise Groups

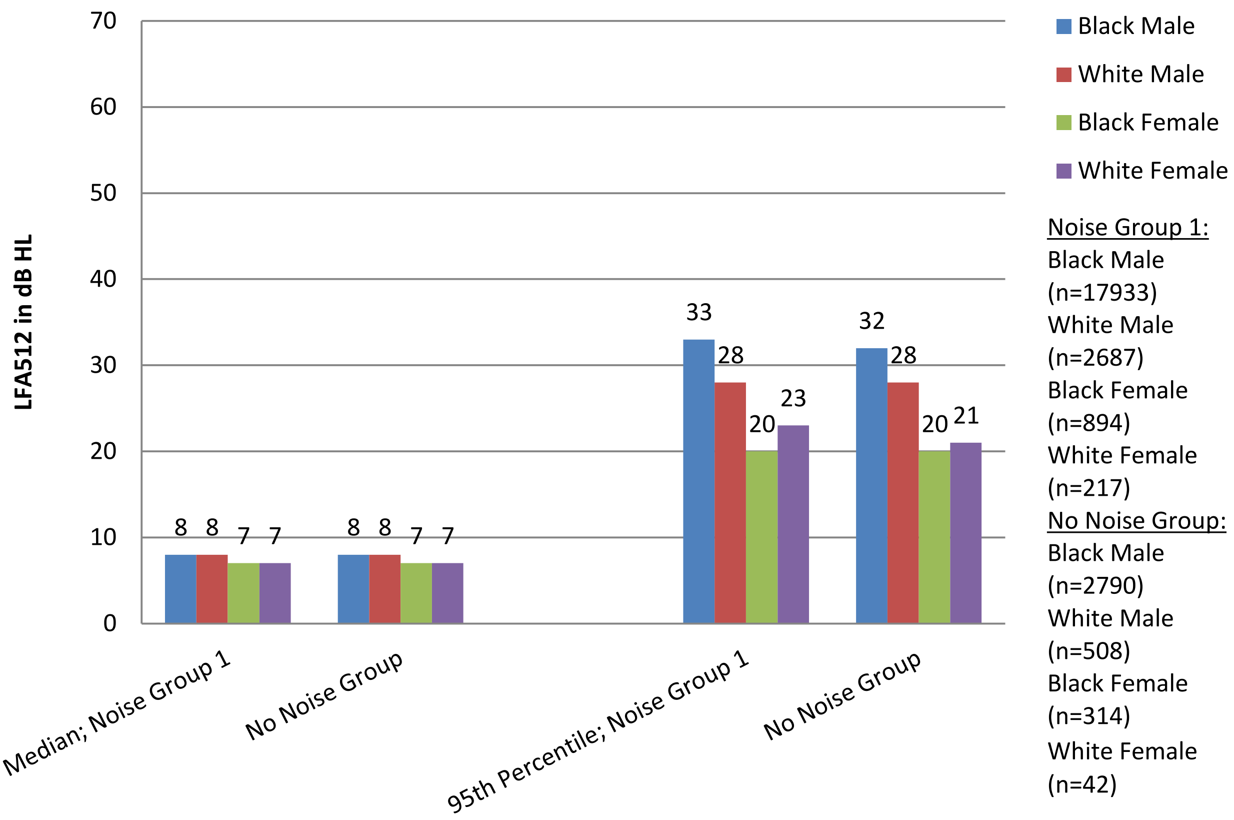


Figure 5-13 Median and 95th percentile values of the low frequency average for thresholds at 0,5, 1, 2 kHz, (LFA512) compared for the different race and gender groups within the different Noise Groups frequency (Noise Group 1: Underground occupational noise ≥85 dB A TWA (n= 33961); No Noise Group: No known occupational noise (n=6194))

From figures 5.12 and 5.13 it is clear that the median and 95th percentile values for the HFA346 (figure 5.12) was larger (more elevated) for all groups that the LFA512 values (figure 5.13). Differences between results for the two noise groups were very small (>5 dB) for all race/gender groups. The difference between the median values for the HFA346 and the LFA512 for the male groups (white and black) and the female groups (black and white) was larger for the HFA346 values than for the LFA512 values. The HFA346 median values for females were ≈8dB better for females than for males compared to the 1 dB difference for male and female median values for the LFA512 results. This was true for both noise groups. A very large difference was observed between the male and female groups for the 95th percentile values for the HFA346. The female 95th percentile values (black and white) were between 20 and 30 dB better (25-30 dB HL) than those of the male groups, black and white, 50-63 dB HL, for both noise groups.

For 95th percentile values, HFA346, the white male group showed poorer threshold averages than the black male group (Noise Group 1 and the No Noise Group). When comparing the HFA346 and the LFA512 values a reverse trend is seen in terms of the 95th percentile values for the black and white males, where the black males had a 10 dB better HFA346 value (53 dB HL) than the white males (63 dB HL) but the black males had a 5 dB more elevated LFA512 value (33 dB HL) than the 95th percentile value for the LFA512 for white males (28 dB HL). This reverse trend was apparent for participants in the male groups in Noise Group 1 and the No Noise Group.

5.4. Sub aim 3: Prevalence and degree of hearing loss as a function of occupation / noise-exposure level

In order to understand the effect of the occupational noise-exposure level as well as the exposure level over time participants in Noise Group 1 were divided into different age groups and then further divided according to their working years (exposed to noise levels ≥ 85 dB A TWA). 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. Two groups were selected because of their homogeneous exposure levels. These groups were the drillers (noise exposure ≥ 90 dB A) and the administration group, including accountants and administrative workers with no known occupational noise exposure.

5.4.1. Prevalence and degree of hearing loss as a function of noise exposure time by age group and across individual frequencies

Participants in Noise Group 1 were divided into different age groups and then further divided into the number of years that they had been working. The working years were categorised into 5 year intervals and data of participants for which the “engage date” (date of commencement of work) were available were included in the analyses. The duration of this working period is based on the assumption that hearing thresholds (±10 dB HL) are stable over a period of 5 years for a similar level of noise exposure or a reduction of such exposure (Picard, et al., 2008). The number of participants in each of the age groups and each of the working years' categories are tabled in table 5.8 below.

Table 5-8 Number of participants in each age group, categorised according to their working years (Noise Group 1: Underground occupational noise ≥85 dB A TWA)

Working years	16 to 30yrs	31 to 40yrs	41 to 50yrs	51 to 60yrs	61 to 65yrs	Total N
0 - 5yrs	3575	2965	1805	450	60	8855
>5 - 10yrs	554	1610	1098	253	13	3528
>10 - 15yrs	25	1627	1011	213	7	2883
>15 - 20yrs	-	770	3087	1228	44	5134
Total	4154	6972	7001	2144	124	20400

Median values for hearing thresholds across the frequency range were calculated for each "working years" category and are shown per age group in figures 5.14 to 5.18.

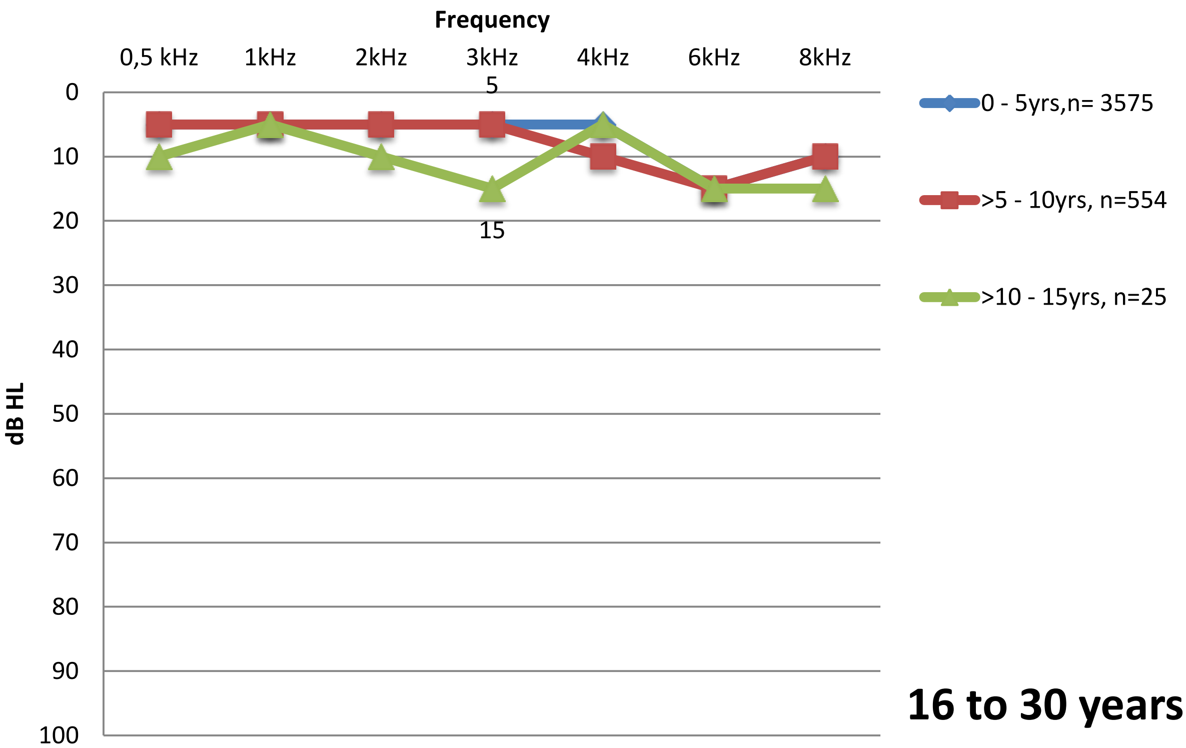


Figure 5-14 Median thresholds per frequency for the age group 16 to 30 years categorised by their working years (Noise Group 1, occupational noise 85 dB TWA)

In the age group 16 to 30 years (figure 5.14) the largest difference in median thresholds of 10 dB were observed at 3 kHz between the group who worked between 0 to 5 years (median= 5 dB HL) compared to the group who had been working between 10 and 15 years (median= 15 dB HL). All other differences were 5 dB or less.

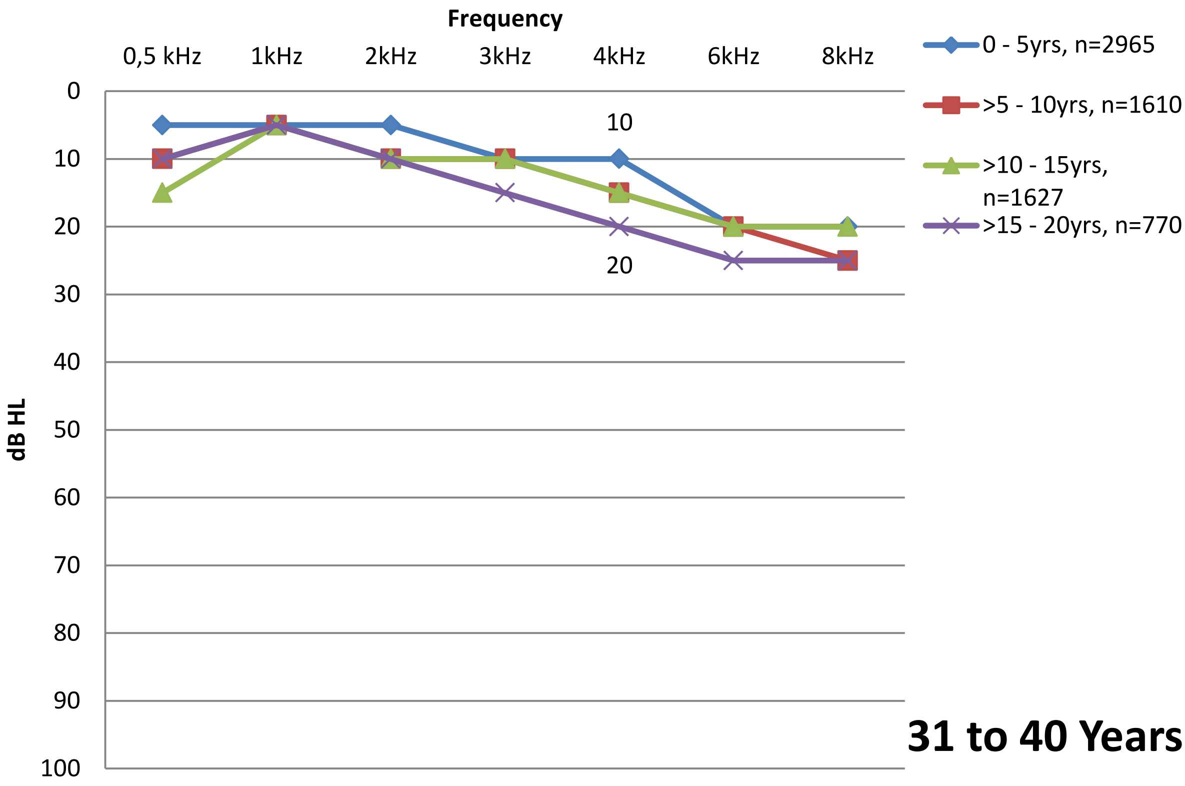


Figure 5-15 Median thresholds per frequency for the age group 31 to 40 years categorised by their working years (Noise Group 1, occupational noise 85 dB TWA)

Median threshold values for the age group 31 to 40 years (figure 5.15) showed the smallest values and better thresholds for the group that had worked between 0 and 5 years, followed by the groups who had worked >5 to 10 years and >10 to 15 years. The median audiograms for these two “working years” categories are very similar, thresholds at 0,5 and 8 kHz differing with 5 dB. The most elevated median thresholds (greatest values) were observed for the 15 to 20 “working years” category. The largest difference in median thresholds (10 dB) was calculated at 4 kHz between the 0 to 5 “working years” category and the 15 to 20 “working years” category.

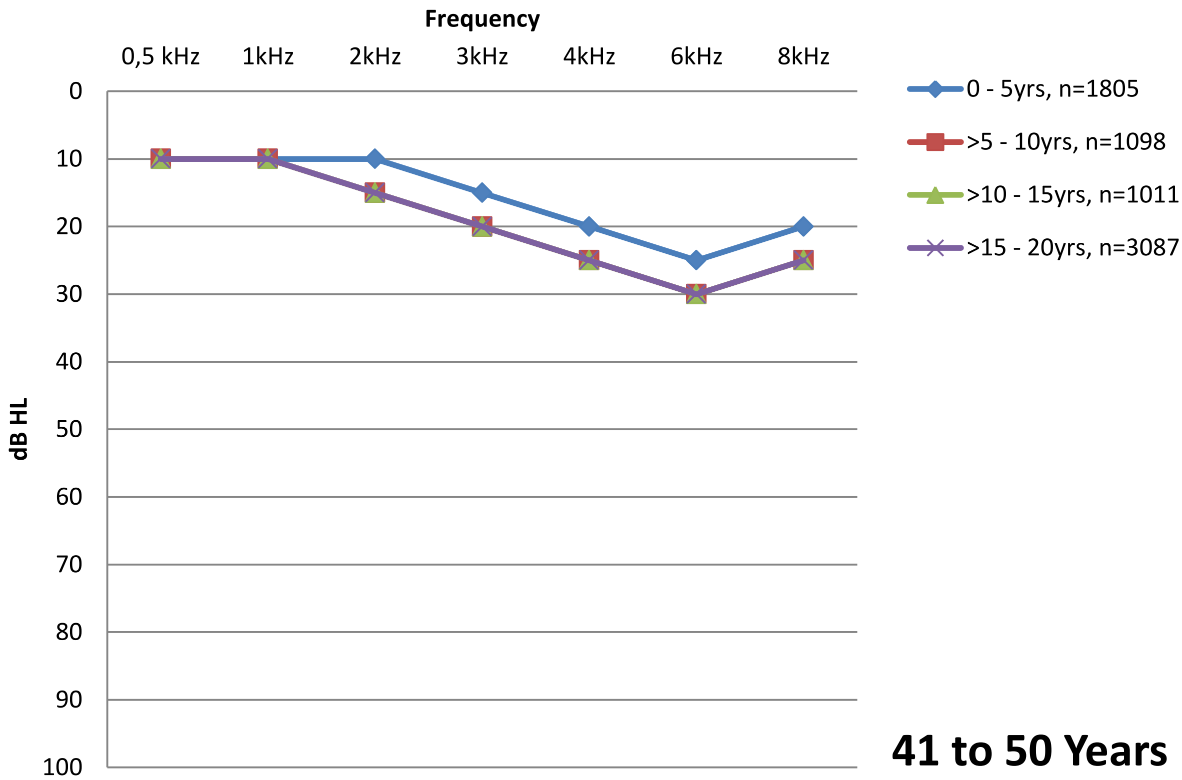


Figure 5-16 Median thresholds per frequency for the age group 41 to 50 years categorised by their working years (Noise Group 1, occupational noise 85 dB TWA)

For the age group 41 to 50 years (figure 5.16) no differences were observed for the median thresholds of workers who had worked between 5 and 20 years. The thresholds at all three “working years” categories (>5 to 10yrs, >10 to 15yrs, and >15 to 20yrs) showed a 5 dB difference in median thresholds across the frequencies between 1 and 8 kHz for the workers who had worked less than 5 years. Compared to median thresholds for the age groups 16 to 30 and 31 to 40 these groups’ thresholds were poorer as can be expected based on the increase in age (compared with figure 5.16 and 5.17).

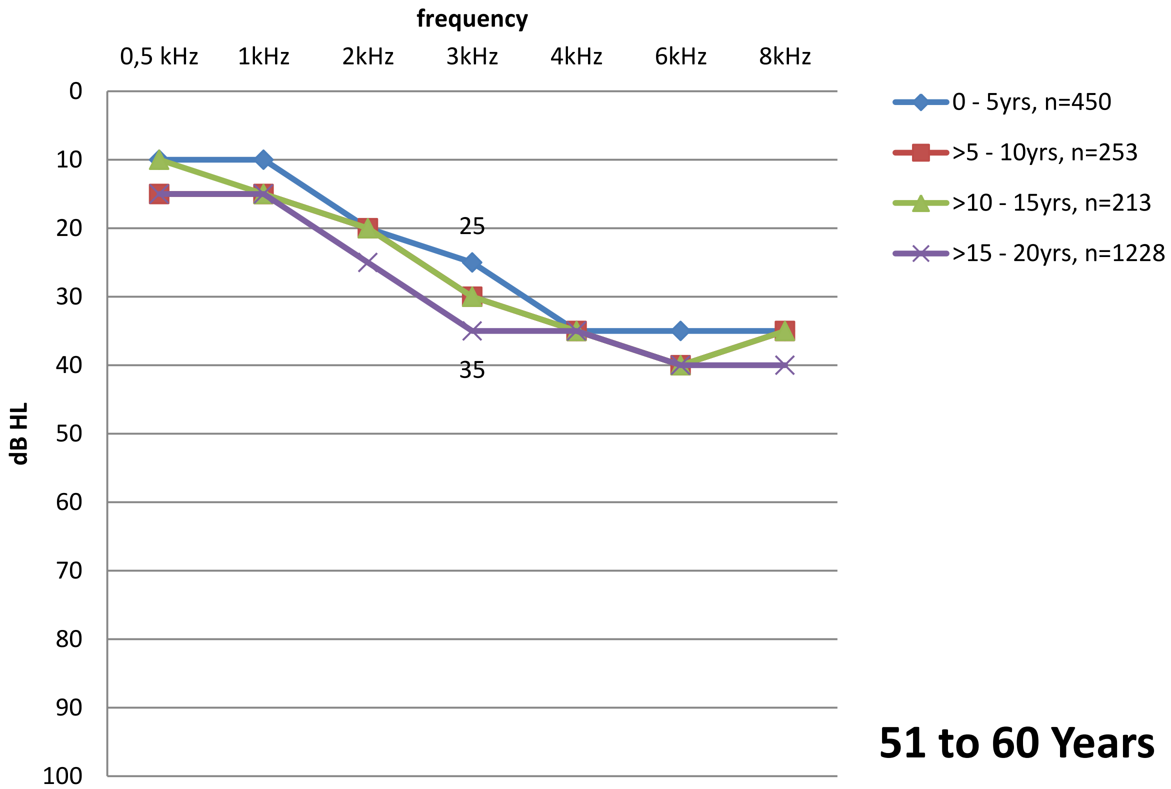


Figure 5-17 Median thresholds per frequency for the age group 51 to 60 years categorised by their working years (Noise Group 1, occupational noise 85 dB TWA)

As was seen in figure 5.14 results shown in figure 5.17 revealed the largest difference in median thresholds of 10 dB between the “working years’ categories 0 to 5 years and 15 to 20 years at 3 kHz. It is clear from figure 5.20 that median thresholds got increasingly more elevated as the working years increased.

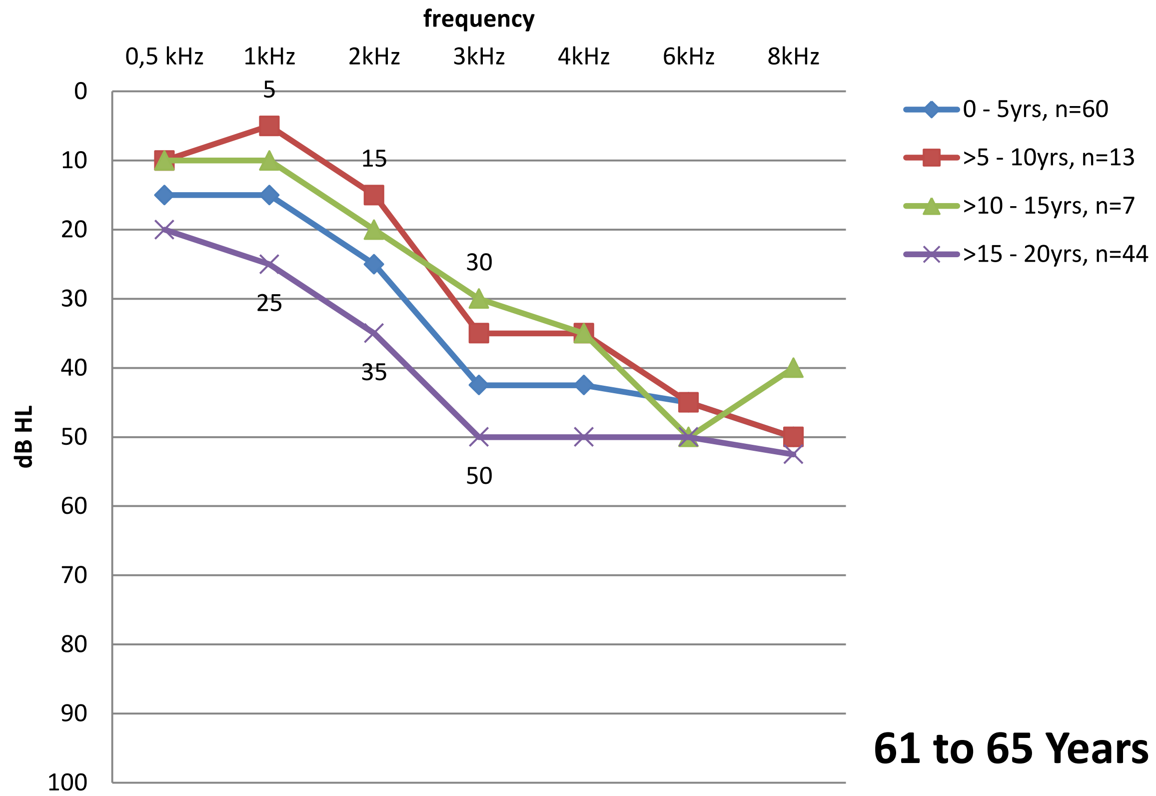


Figure 5-18 Median thresholds per frequency for the age group 61 to 65 years categorised by their working years (Noise Group 1, occupational noise 85 dB TWA)

Differences between the participants in the different "working years" categories were the most obvious for the age group 61 to 65 years (figure 5.18) compared to the other age groups (figure 5.14-5.18). As was shown in figure 5.14 and 5.17 the largest difference (20 dB) in this age group was observed at 3 kHz between the workers who had less than 5 years' experience (30 dB HL) and the workers with more than 15 years' experience (50 dB HL). 20 dB differences were also observed at 1 and 2 kHz between the group with 5 to 10 years' working experience and the group with more than 15 year's working experience.

5.4.2. Prevalence and degree of hearing loss as a function of noise- exposure level for homogenous exposure groups across individual frequencies

To investigate the effect of noise exposure on the hearing of miners, sub groups were defined within Noise Group 1 and the No Noise Group. 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 (Franz & Phillips, 2001). The administration group are administrative workers who have not previously been exposed to occupational noise. This group is defined as “admin”. Figures 5.19 and 5.20 show the number of participants for these two HEGs (administration and driller) categorised by race, gender, and age group.

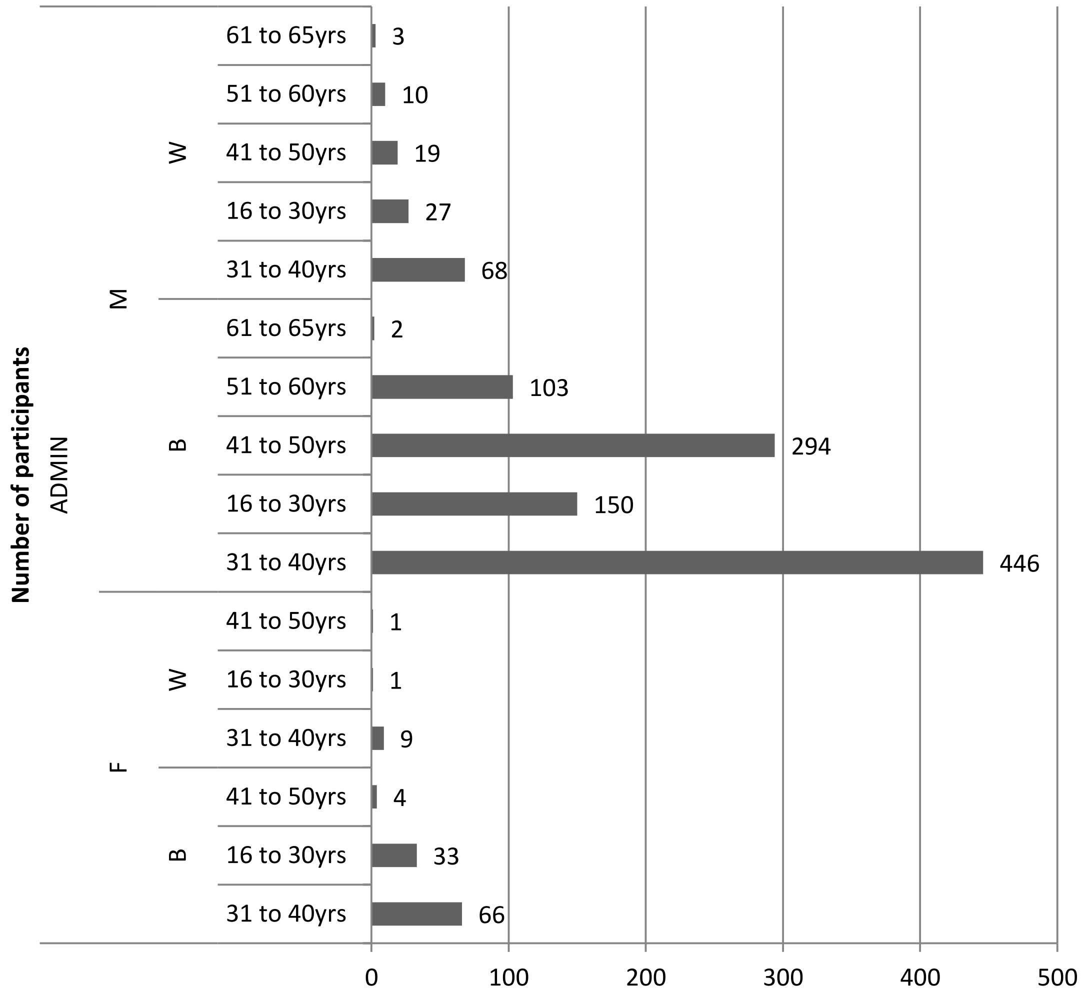


Figure 5-19 Number of participants for the administration group per race and gender and age category

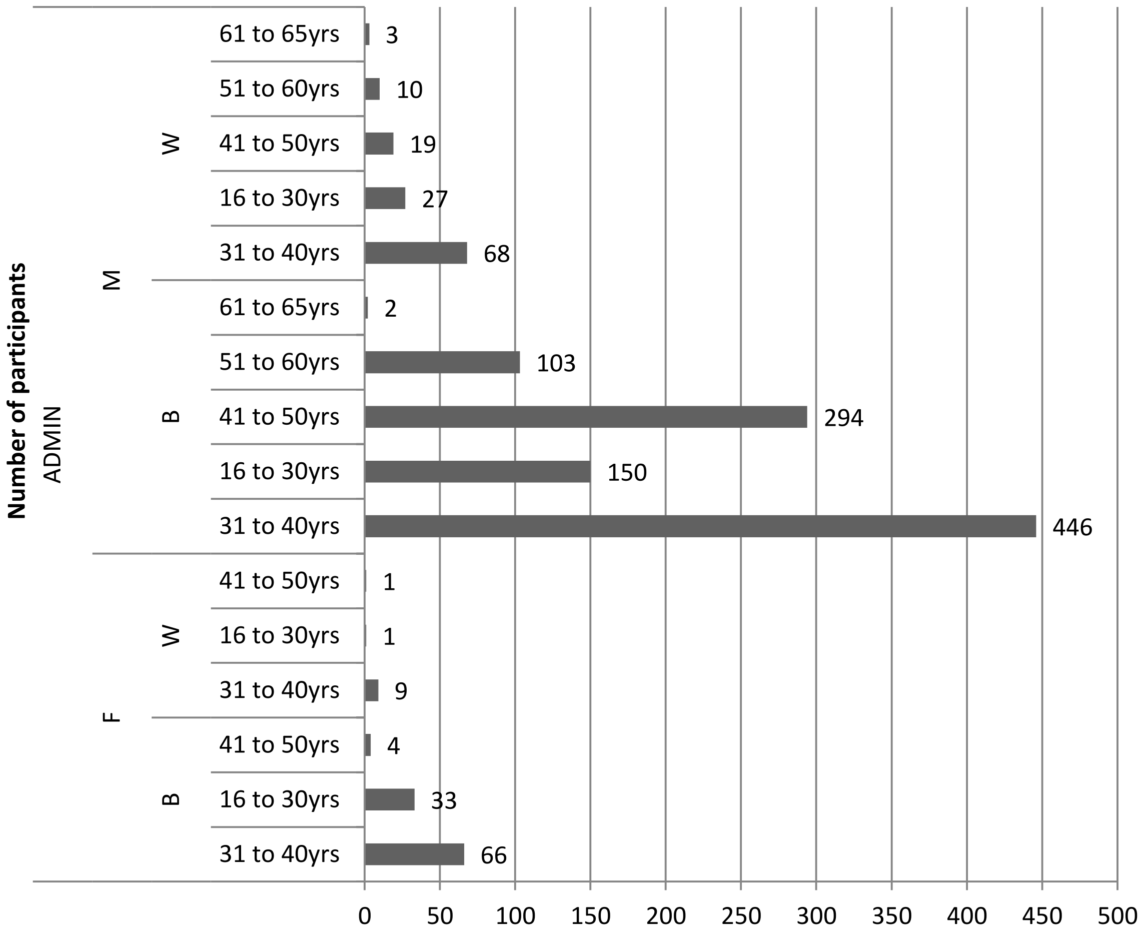


Figure 5-20 Number of participants for the driller group per race and gender group

From figures 5.19 and 5.20 it is clear that the driller as well as administration group were represented mostly by black male participants. In the administration group most of these black, male participants were between 31 and 40 years followed in numbers by participants between 41 and 50 years. In the driller group most black, male participants were between 41 and 50 years followed in numbers by participants between 51 and 60 years.

In figure 5.21 median and 95th percentile values of these two HEGs (all participants in the groups) for thresholds across the frequency range were compared. As seen in the previous two figures (figures 5.19 and 5.20) it is clear that the participants in the driller group were slightly older that those in the administration group and results in Figure 5.21 might be influenced. In figure 5.22 results (median and 95th percentile threshold values per frequency) for black, male participants in three age categories, 31 to 40 years, 41 to 50 years and 51 to 60 years were selected and shown. The other age categories had too little participants to compare results.

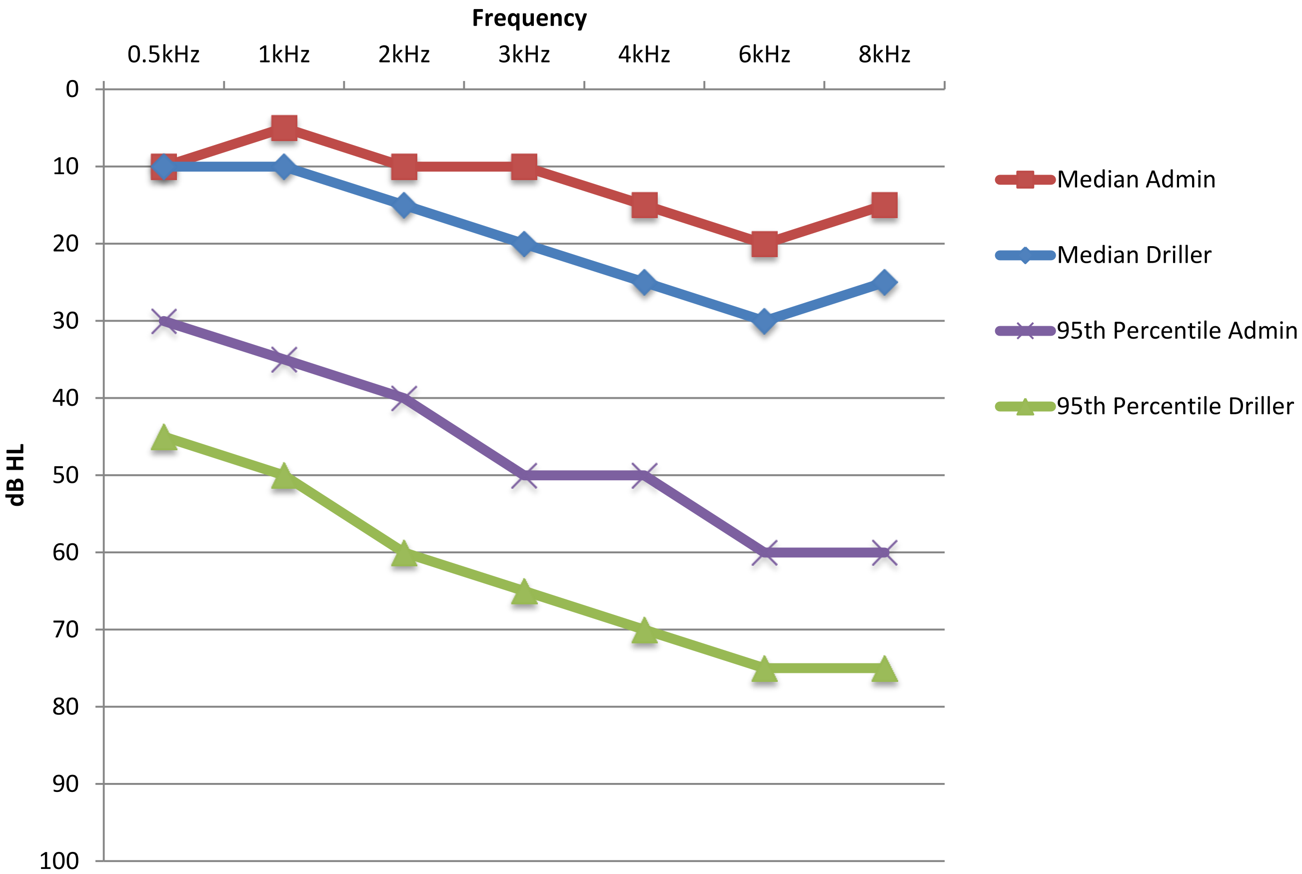


Figure 5-21 Median and 95 th Percentile values for thresholds (in dB HL) across the frequency range for homogenous exposure groups (HEGs); Drillers and Admininstration (Admin)

From figure 5.21 it is clear that median as well as 95th percentile values of hearing thresholds across the frequency spectrum are very different for the administration and driller sub groups. All values of the drillers were markedly more elevated (higher) than those for the administration group. In the frequency range from 3 to 8 kHz median thresholds for the drillers were 10dB more elevated than those for the administration group. 95th percentile values for drillers range between 45 dB HL and 75 dB HL compared to the 30 and 60 dB HL range for the administration group. Across the frequency spectrum drillers' thresholds (95th percentile) are approximately 20 dB more elevated than those of the administration group. When compared to the difference between median and 95th percentile values of Noise Group 1 compared to the No Noise Group, (see figures 5.5 and 5.6) the differences observed in figure 5.21 for these HEGs are much greater. As shown in figures 5.19 and 5.20 the administration and driller groups are not the same in terms of the age, gender and race distribution and results might be influenced by these factors.

In order to address these differences a sub group within the driller and administration groups of similar age, gender, and race was selected to aid comparison. The sub groups (black, male participants in different age categories) were selected based on the number of available participants (see figure 5.19 and 5.20). 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. These values are shown in figures 5.22 and 5.23.

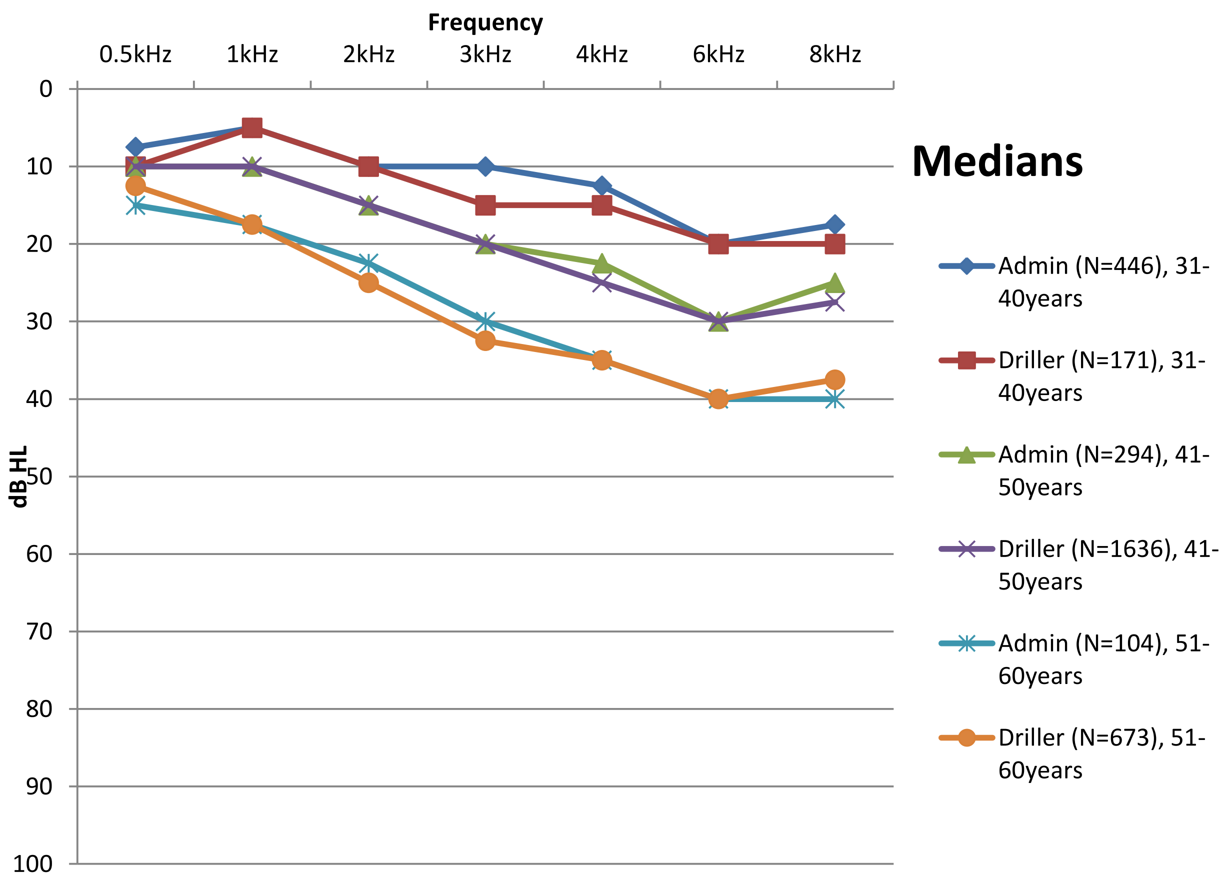


Figure 5-22 Median values for thresholds (in dB HL) across the frequency range for black, male participants in the Driller and Administration (admin) groups, for ages 31 to 40 years, 41 to 50 years, and 51 to 60 years

The largest difference between the median values for the administration and driller groups (figure 5.22) was observed in the black, male group for the age group 31 to 40 years at 3000Hz (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). Figure 5.23 shows the 95th percentile values for these sub groups.

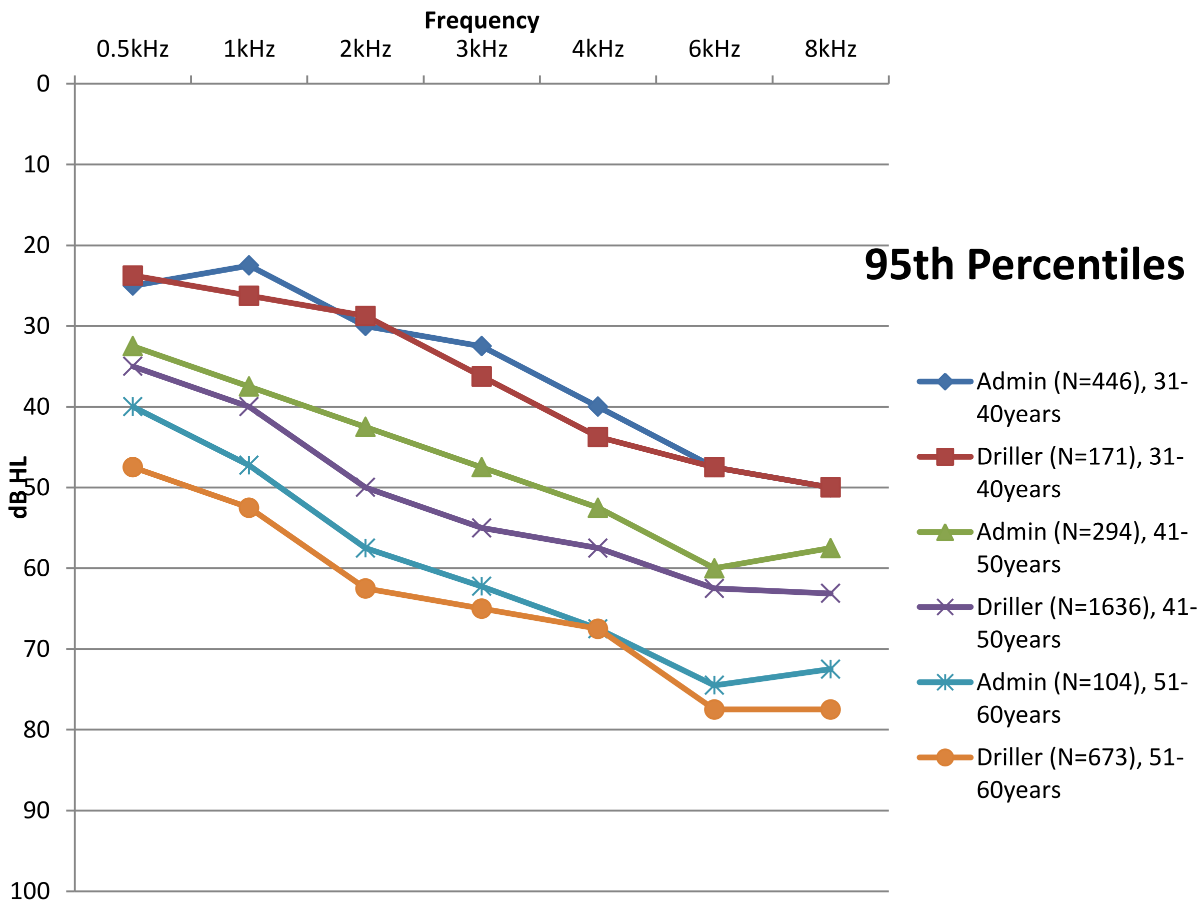


Figure 5-23 95th Percentile values for thresholds (in dB HL) across the frequency range for Black, Male participants in the Driller and Administration (admin) group, for ages 31 to 40 years, 41 to 50 years, and 51 to 60 years

The differences between 95th percentile values for the driller and administration groups shown in figure 5.23 were smaller than those observed in figure 5.21 when age, gender, and racial differences were not taken into account. 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 drillers more than 5 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 is observed that the thresholds values of these two groups came closer in values as the frequencies became higher.

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

5.5. Sub aim 4: The combined effect of various biographical, environmental and work-related variables on hearing status

To asses the combined effect of various variables on the hearing status of goldminers, threshold distributions were compared to demographically matched control groups to evaluate if hearing thresholds are typical for a matched demographic group. Comparisons with a matched demographic group can be used to describe whether a person's status is typical (Flamme, et al., 2011). A synthesis of reported effects culminated in the development of the ISO 1990:1999 and the nearly identical ANSI S3.44 (1996) guidelines. Both international (ISO 1990:1999) and United States of America (ANSI S3.44-1996) standards describe the distributions of hearing thresholds (10th, 50th, and 90th percentiles, for 0,5 to 6 kHz) associated with age and gender. ISO 1990:1999, Annex B of ISO 1990:1999, was used to compare data with as this annex includes some people with occupational noise exposure, but is otherwise more representative of the general population (Dobie, 2006). In a study by (Hoffman, Dobie, Ko, Themann, and Murphy (2010) hearing threshold data from the nationally representative survey in the United States (National Health and Nutrition Examination Survey, 1999–2004) were presented as a possible replacement for Annex B in ISO 1990:1999 and ANSI S3.44. Age groups as defined by the ISO 1990:1999 are 25 to 34 years, 35 to 44 years, 45 to 54 years and 55 to 64 years. Annex B (ISO 1990:1999) distributions represent better ear hearing levels. For these comparisons the best (lowest) threshold across ears was selected at each frequency (Flamme, et al., 2011). The ISO 1990:1999 does not stratify the results for the different race groups. ANSI S3.44 offers Annex C in addition to Annex A and Annex B which gives threshold distributions for people who have never had noisy jobs (Hoffman, Dobie, Ko, Themann, & Murphy, 2010). Data in this Annex C are categorised into different race and gender categories. Hearing thresholds of the cohort (with daily noise exposure above 85 dB A as well as the No Noise group) were compared to these standards. Annex B distributions represent better ear hearing levels. For these comparisons the best (lowest) threshold across ears was selected at each frequency (Flamme, et al., 2011). Annex C (ANSI S3.4, 1996) distributions represent binaural averages and these were calculated and used for comparisons. It is also important to note that the current study used the conventional method for calculating the median, where for example the median of a group of 15 would be simply the 8th-ranked value. The ISO 1990:1999, ANSI S3.44 (1996) and the Hoffman, Dobie, Ko, Themann & Murphy (2010) studies calculated the median for grouped data, assuming that the cases in each 5-dB interval are evenly distributed (Dobie, 2006). The five "15 dB" cases would be redefined as 13, 14, 15, 16, and 17 dB and the five "20 dB" cases as 18, 19, 20, 21, and 22 dB. The median is the 8th-ranked case in this new distribution (18 dB).

Table 5.9 shows the number of subjects included in each of the age groups as defined by the ISO 1990:1999.

Table 5-9 Number of participants of the study per age group (as defined by ISO 1990:1999)

Age category using ISO age groups	N	Percentage of available sample (%)
25 to 34yrs	15 770	30,04%
35 to 44yrs	19 279	36,72%
45 to 54yrs	13 786	26,26%
55 to 64yrs	3 662	6,98%
Total	52 497	100%

Table 5-10 Hearing-threshold level (in dB HL) for the No Noise Group (no known occupational noise exposure) for men and female of different ages

Hearing-threshold level (dB HL) Age* No Noise Group (no occupational noise exposure)																				
	30					40					50					60				
Percentiles																				
Frequency (Hz)	5	0	50	90	95	5	10	50	90	95	5	10	50	90	95	5	10	50	90	95
Men	n= 953					n=1205					n=829					n=150				
500	0	0	5	10	15	0	0	5	15	20	0	0	5	20	25	0	0	10	30	35
1000	0	0	5	10	15	0	0	5	15	20	0	0	5	25	30	0	5	10	40	45
2000	0	0	5	15	20	0	0	5	20	25	0	0	10	35	40	5	5	20	45	55
3000	0	0	5	15	20	0	0	10	25	35	0	5	15	45	50	5	10	25	55	60
4000	0	0	5	20	25	0	0	10	30	40	5	5	20	45	55	10	10	32.5	60	65
6000	0	0	10	25	30	5	5	20	35	45	5	10	25	50	55	15	15	35	65	70
8000	0	0	10	25	30	0	0	15	35	50	5	5	20	50	55	10	10	30	62.5	70
Female	n=157					n=129					n=38					n=no data				
500	0	0	5	15	15	0	0	5	15	15	0	0	5	20	45					
1000	0	0	0	10	15	0	0	5	10	15	0	0	5	20	35					
2000	0	0	0	10	15	0	0	5	15	15	0	0	10	20	30					
3000	0	0	0	10	20	0	0	5	15	15	0	0	5	25	25					
4000	0	0	5	10	20	0	0	5	15	15	0	0	5	25	30					
6000	0	0	5	25	30	0	0	10	20	25	0	5	15	30	40					
8000	0	0	5	20	30	0	0	10	25	25	0	0	10	40	50					

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

Table 5-11 Hearing-threshold level (in dB HL) for Noise Group 1 (underground occupational noise exposure ≥ 85 dB A) for men and female of different ages

Hearing-threshold level (dB HL)
Age*
Noise Group 1(underground occupational noise exposure)

	30					40					50					60				
Percentiles																				
Frequency (Hz)	5	0	50	90	95	5	10	50	90	95	5	10	50	90	95	5	10	50	90	95
Men	n= 4718					n=7898					n=5728					n=1058				
500	0	0	5	10	15	0	0	5	15	20	0	0	5	20	25	0	0	10	25	35
1000	0	0	5	10	15	0	0	5	15	20	0	0	5	25	30	0	0	10	40	45
2000	0	0	5	15	20	0	0	5	20	30	0	0	10	35	45	0	5	20	45	55
3000	0	0	5	15	20	0	0	10	30	35	0	5	15	45	50	5	5	25	55	60
4000	0	0	5	15	20	0	0	10	35	40	0	5	20	45	55	5	10	30	60	65
6000	0	0	10	25	30	5	5	20	35	45	5	10	25	50	60	10	15	35	65	70
8000	0	0	10	25	30	0	5	15	35	45	5	5	20	50	60	5	10	35	65	75
Female	n=463					n=238					n=128					n=42				
500	0	0	5	15	20	0	0	5	15	15	0	0	10	20	25	5	5	10	25	25
1000	0	0	0	10	10	0	0	5	10	15	0	0	5	15	20	0	0	10	25	35
2000	0	0	5	10	15	0	0	5	15	20	0	0	5	20	35	5	5	10	25	35
3000	0	0	5	10	15	0	0	5	15	20	0	0	10	20	25	5	5	10	25	45
4000	0	0	0	10	15	0	0	5	15	15	0	0	10	20	30	0	5	10	25	65
6000	0	0	10	20	25	0	0	10	25	30	5	10	15	35	45	10	10	20	50	65
8000	0	0	10	25	30	0	0	10	25	35	5	5	15	40	50	5	5	25	60	70

*Age is grouped in 10yr intervals, that is, '30' represents ages 25 to 34 yrs, etc.
Thresholds differ from those of No Noise group (Table 5.10) where values of the Noise Group 1 is more than No Noise Group
Underline where No Noise group values are higher (worse) than Noise Group 1

Table 5-12Hearing-threshold level (in dB HL) for Administration Group (no known occupational noise exposure) for men and female of different ages

Hearing-threshold level (dB HL) Age* ADMINISTRATION																				
Percentiles	30					40					50					60				
Frequency (Hz)	5	10	50	90	95	5	10	50	90	95	5	10	50	90	95	5	10	50	90	95
Men	N= 412					N=401					N=249					N=62				
500	0	0	5	10	15	0	0	5	15	20	0	0	10	20	25	0	5	10	35	45
1000	0	0	5	10	15	0	0	5	15	20	0	0	10	30	35	0	5	15	45	50
2000	0	0	5	15	20	0	0	5	20	25	0	0	15	35	45	5	5	20	55	60
3000	0	0	5	15	20	0	0	10	25	35	0	5	20	45	50	5	5	30	60	60
4000	0	0	5	20	25	0	0	10	30	35	5	5	20	45	55	10	10	35	65	65
6000	0	0	10	25	30	0	5	20	35	40	5	10	25	50	60	10	15	37.5	70	75
8000	0	0	10	25	30	0	0	15	35	40	5	5	20	50	55	10	10	40	65	80
Female	N=80					N=33					N=3					No data				
500	0	0	5	15	20	0	0	5	10	20	5	5	5	5	5					
1000	0	0	5	15	15	0	0	5	10	15	5	5	5	20	20					
2000	0	0	5	15	20	0	0	5	15	15	5	5	5	20	20					
3000	0	0	5	20	22.5	0	0	5	10	10	0	0	5	15	15					
4000	0	0	5	17.5	22.5	0	0	5	15	15	5	5	5	25	25					
6000	0	0	10	30	35	5	5	10	20	25	5	5	5	25	25					
8000	0	0	7.5	30	37.5	0	0	10	25	30	15	15	15	20	20					

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

Table 5-13 Hearing-threshold level (in dB HL) for drillers (underground occupational noise exposure ≥ 90 dB (A)) for men and female of different ages

Hearing-threshold level (dB HL) Age* DRILLER																				
	30					40					50					60				
	Percentiles																			
Frequency (Hz)	5	0	50	90	95	5	10	50	90	95	5	10	50	90	95	5	10	50	90	95
Men	n=256					n=1304					n=2277					n=505				
500	0	0	5	15	15	0	0	5	20	25	0	0	10	25	30	0	5	15	35	55
1000	0	0	5	10	10	0	0	5	20	35	0	0	10	35	45	0	0	15	50	55
2000	0	0	5	10	15	0	0	10	30	40	0	5	15	40	50	0	5	20	55	65
3000	0	0	5	15	15	0	0	10	35	45	0	5	20	45	50	5	5	30	60	70
4000	0	0	5	15	20	0	0	15	40	50	0	5	20	50	55	5	10	30	60	70
6000	0	0	10	25	30	5	5	20	40	55	5	10	25	50	60	10	15	35	75	85
8000	0	0	5	20	25	0	0	15	40	50	5	5	20	50	65	5	10	35	70	85
Fe-male	n=46					n=38					n=53					n=17				
500	0	0	5	10	15	0	0	7.5	15	15	0	0	10	15	25	5	5	10	30	60
1000	0	0	5	10	10	0	0	5	10	15	0	0	5	15	20	0	0	10	40	50
2000	0	0	0	10	10	0	0	5	15	20	0	0	5	20	25	5	5	10	45	55
3000	0	0	5	10	20	0	0	5	15	15	0	0	5	20	30	5	5	10	60	90
4000	0	0	2.5	15	15	0	0	0	15	15	5	5	10	20	35	0	0	10	65	85
6000	0	0	10	25	25	5	5	10	25	30	0	10	15	30	45	0	10	25	65	95
8000	0	0	5	25	40	0	0	5	25	30	0	5	15	35	50	5	5	25	65	95

*Age is grouped in 10yr intervals, that is, '30' represents ages 25 to 34 yrs, etc.
5 dB or more difference with thresholds of the administration group (drillers values higher (worse) than administration)
Underline where administration values are worse than driller values

Table 5-14 Hearing thresholds (in dB HL) for men in the No Noise group (no known occupational noise exposure) for different race and age groups

	Hearing-threshold level (dB HL) Age* No Noise Group (no known occupational noise exposure)											
	30			40			50			60		
	Percentile											
Frequency (Hz)	10	50	90	10	50	90	10	50	90	10	50	90
Black Men	n=791			n=1016			n=693			n=115		
500	0	5	17,5	0	7,5	20	2,5	10	25	5	12,5	35
1000	0	5	15	0	7,5	20	2,5	10	30	5	15	42,5
2000	0	7,5	20	2,5	10	27,5	5	15	40	7.5	22,5	47,5
3000	0	7,5	20	2,5	12,5	32,5	7,5	20	45	10	30	55
4000	2,5	7,5	25	5	15	35	10	25	47,5	15	35	60
6000	5	17,5	32,5	10	22,5	45	15	30	52,5	20	37,5	67,5
8000	5	12,5	32,5	7,5	20	45	12,5	27.5	55	17.5	37,5	67,5
White men	n=554			n=877			n=693			n=243		
500	0	5	15	2,5	7,5	22,5	5	12,5	27,5	3,75	13,7	30
1000	0	5	12,5	0	7,5	20	5	12,5	27,5	5	12,5	46,2
2000	0	5	15	25	10	22,5	5	15	40	8,75	28,7	55
3000	2,5	7.5	20	2,5	12,5	35	10	25	62,5	16,2	50	68,7
4000	2,5	10	25	5	20	47,5	12,5	32,5	65	26,2	50	73,5
6000	5	15	32,5	10	22,5	55	17,5	32,5	65	30	57,5	76
8000	0	12.5	27,5	5	17,5	47,5	15	30	67,5	25	53,7	82,5

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

Table 5-15 Hearing thresholds (in dB HL) for men in Noise Group 1 (underground noise exposure of ≥ 85 dB A) for different race and age groups

Hearing-threshold level (dB HL) Age* Noise Group 1(underground occupational noise exposure)												
	30			40			50			60		
	Percentile											
Frequency (Hz)	10	50	90	10	50	90	10	50	90	10	50	90
Black Men	n=4133			n=6965			n=5000			n=806		
500	0	5	17,5	0	7,5	20	2,5	10	25	5	15	35
1000	0	5	15	0	7,5	22,5	2,5	10	32,5	5	15	45
2000	0	7,5	17,5	2,5	10	27,5	5	17,5	40	7,5	25	52,5
3000	0	7,5	20	2,5	12,5	35	7,5	22,5	47,5	10	32,5	60
4000	2,5	7,5	22,5	5	17,5	37,5	10	25	50	15	35	62,5
6000	5	17,5	32,5	10	22,5	45	15	30	55	20	40	70
8000	2,5	12,5	30	7,5	20	45	12,5	27,5	57,5	17,5	40	70
White men	n=2367			n=146			n=121			n=30		
500	0	5	15	0	5	15	2,5	10	25	5	12,5	25
1000	0	5	12,5	0	5	17,5	2,5	10	25	5	12,5	30
2000	0	5	15	2,5	7,5	22,5	5	12,5	35	7,5	20	45
3000	0	7,5	22,5	5	15	37,5	7,5	25	57,5	15	37,5	62,5
4000	2,5	10	27,5	5	20	47,5	12,5	32,5	60	22,5	45	67,5
6000	5	15	32,5	7,5	22,5	47,5	17,5	35	65	25	47,5	75
8000	2,5	10	25	5	20	47,5	10	30	65	20	50	80

*Age is grouped in 10yr intervals, that is, '30' represents ages 25 to 34 yrs, etc.
Noise Group 1 values higher (worse) than No Noise values
Underline where No Noise values worse than Noise Group 1 values

Table 5-16 Median threshold values across frequencies for male participants of the No Noise Group and Noise Group 1 categorised by age and compared to ISO 1990:1999 Annex B, as well as Hoffman, Dobie, Ko, Themann, & Murphy (2010)'s proposed new Annex B

A.		Median threshold values of better ear			
MALE		NO NOISE GROUP (Total n:3137)	ISO 1990:1999-Annex B (1990)	Proposed new Annex B (Hoffman, Dobie, Ko, Themann, & Murphy, 2010)	NOISE GROUP 1 (Total n:19402)
Age Group*	Frequency (kHz)				
30	0,5	5	7	7	5
Noise Group 1 (n=4718) No Noise Group (n=953)	1	5	0	4	5
	2	5	2	4	5
	3	5	9	4	5
	4	5	10	7	5
	6	10	18	11	10
	8	10	---	8	10
40	0,5	5	8	8	5
Noise Group 1 (n=7898) No Noise Group (n=1205)	1	5	3	6	5
	2	5	4	6	5
	3	10	13	9	10
	4	10	17	13	10
	6	20	24	17	20
	8	15	---	14	15
50	0,5	5	10	10	5
Noise Group 1 (n=5728) No Noise Group (n=829)	1	5	5	9	5
	2	10	8	10	10
	3	15	19	15	15
	4	20	26	22	20
	6	25	31	25	25
	8	20	---	23	20
60	0,5	10	12	11	10
Noise Group 1 (n=1058) No Noise Group (n=150)	1	10	6	11	10
	2	20	10	14	20
	3	25	30	25	25
	4	32,5	36	35	30
	6	35	46	40	35
	8	30	----	42	35

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

Table 5-17 Median threshold values across frequencies for female participants of the No Noise Group and Noise Group 1 categorised by age and compared to ISO 1990:1999 Annex B, as well as Hoffman, Dobie, Ko, Themann, & Murphy (2010)'s proposed new Annex B

B.		Median threshold values of better ear			
FEMALE Age Group*	Frequency (kHz)	NO NOISE GROUP (Total n:325)	ISO 1990:1999-Annex B (1990)	Proposed new Annex B (Hoffman, Dobie, Ko, Themann, & Murphy, 2010)	NOISE GROUP 1 (Total n:871)
30 Noise Group 1 (n=463) No Noise Group (n=157)	0,5	5	6	7	5
	1	0	1	4	0
	2	0	0	4	5
	3	0	4	2	5
	4	5	4	4	0
	6	5	12	10	10
	8	5	---	7	10
40 Noise Group 1 (n=238) No Noise Group (n=129)	0,5	5	7	7	5
	1	5	2	5	5
	2	5	2	5	5
	3	5	6	4	5
	4	5	6	7	5
	6	10	15	12	10
	8	10	---	10	10
50 Noise Group 1 (n=128) No Noise Group (n=38)	0,5	5	10	10	10
	1	5	4	9	5
	2	10	6	10	5
	3	5	9	15	10
	4	5	9	22	10
	6	15	20	25	15
	8	10	---	23	15
60 Noise Group 1 (n=42) No Noise Group (n=0)	0,5	---	14	11	10
	1		7	11	10
	2		8	14	10
	3		16	25	10
	4		17	35	10
	6		29	40	20
	8		----	42	25

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

Table 5-18 Median threshold values across frequencies for male participants of the administration group (admin) and driller group categorised by age and compared to ISO 1990:1999 Annex B, as well as Hoffman, Dobie, Ko, Themann, & Murphy (2010)'s proposed new Annex B

C.		Median threshold values of better ear			
MALE		ADMIN	ISO 1990:1999-Annex B (1990)	Proposed new Annex B (Hoffman, Dobie, Ko, Themann, & Murphy, 2010)	DRILLER
Age Group *	Frequency (kHz)	(Total n: 1124)			(Total N: 4342)
30	0,5	5	7	7	5
ADMIN: n=412 DRILLER: n=256	1	5	0	4	5
	2	5	2	4	5
	3	5	9	4	5
	4	5	10	7	5
	6	10	18	11	10
	8	10	---	8	5
40	0,5	5	8	8	5
ADMIN: n=401 DRILLER: n=1304	1	5	3	6	5
	2	5	4	6	10
	3	10	13	9	10
	4	10	17	13	15
	6	20	24	17	20
	8	15	---	14	15
50	0,5	10	10	10	10
ADMIN: n=249 DRILLER: n=2277	1	10	5	9	10
	2	15	8	10	15
	3	20	19	15	20
	4	20	26	22	20
	6	25	31	25	25
	8	20	---	23	20
60	0,5	10	12	11	15
ADMIN: n=62 DRILLER: n= 505	1	15	6	11	15
	2	20	10	14	20
	3	30	30	25	30
	4	35	36	35	30
	6	37,5	46	40	35
	8	40	----	42	35

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

Table 5-19 Median threshold values across frequencies for male participants of the administration group (admin) and driller group categorised by age and compared to ISO 1990:1999 Annex B, as well as Hoffman, Dobie, Ko, Themann, & Murphy (2010)'s proposed new Annex B

D.		Median threshold values of better ear			
FEMALE		ADMIN (Total n: 116)	ISO 1990:1999-Annex B (1990)	Proposed new Annex B (Hoffman, Dobie, Ko, Themann, & Murphy, 2010)	DRILLER (Total n:154)
Age Group*	Frequency (kHz)				
30	0,5	5	6	7	5
ADMIN: n=80	1	5	1	4	5
DRILLER: n=46	2	5	0	4	0
	3	5	4	2	5
	4	5	4	4	2,5
	6	10	12	10	10
	8	10	---	7	5
40	0,5	5	7	7	7,5
ADMIN: n=33	1	5	2	5	5
DRILLER: n=38	2	5	2	5	5
	3	5	6	4	5
	4	5	6	7	0
	6	10	15	12	10
	8	10	---	10	5
50	0,5	5	10	10	10
ADMIN: n=3	1	5	4	9	5
DRILLER: n=53	2	5	6	10	5
	3	5	9	15	5
	4	5	9	22	10
	6	5	20	25	15
	8	15	---	23	15
60	0,5	----	14	11	10
ADMIN: n=0	1		7	11	10
DRILLER: n=17	2		8	14	10
	3		16	25	10
	4		17	35	10
	6		29	40	25
	8		----	42	25

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

Table 5-20 Median values for binaural average thresholds across the frequency range for white male participants of Noise Group 1 and the No Noise Group, compared to ANSI S3.44 (1996) Annex C

E.		Median values for hearing threshold dB HL Binaural averages								
MALE, White		No Noise Group (Total n:464)			ANSI S3.44 (1996) Annex C			Noise Group 1 (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
No Noise Group: n=554 Noise Group 1: 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
No Noise Group: n=877 Noise Group 1: 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
No Noise Group: n=693 Noise Group 1: 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
No Noise Group: n=243 Noise Group 1: 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.

Table 5-21 Median values for binaural average thresholds across the frequency range for black male participants of Noise Group 1 and the No Noise Group categorised by age compared to ANSI S3.44 (1996) Annex C

F.		Median values for hearing threshold dB HL Binaural averages								
MALE, Black		No Noise Group (Total n:2615)			ANSI S3.44 (1996) Annex C			Noise Group 1 (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
No Noise Group: n=791 Noise Group 1: 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
No Noise Group: n=1016 Noise Group 1: 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
No Noise Group: n=693 Noise Group 1: 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
No Noise Group: n=115 Noise Group 1: 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.

Table 5-22 Median values for binaural average thresholds across the frequency range for black male participants of the driller and administration groups (admin) categorised by age compared to ANSI S3.44 (1996) Annex C

G.		Median values for hearing threshold dB HL Binaural averages								
MALE, Black		Admin (Total n:978)			ANSI S3.44 (1996) Annex C			Driller (Total n:2514)		
Age Group *	Frequency (kHz)									
		Percentiles								
		10	50	90	10	50	90	10	50	90
30	0,5	0	5	15	-1	6	14	0	6,25	15
Admin: n=336	1	0	5	12,5	-4	1	7	0	5	15
Driller: n=54	2	0	7,5	20	-6	0	5	0	7,5	20
	3	0	7,5	22,5	-5	3	13	0	7,5	22,5
	4	0	10	25	-3	3	15	0	10	25
	6	5	17,5	35	-4	5	17	2,5	15	32,5
	8	2,5	15	32,5	----	----	----	2,5	11,25	25
40	0,5	0	7,5	20	-2	5	13	0	10	22,5
Admin: n=365	1	0	7,5	20	-4	2	9	0	7,5	27,5
Driller: n=520	2	2,5	10	25	-5	1	8	2,5	12,5	32,5
	3	2,5	12,5	32.5	-4	5	19	2,5	5	40
	4	2,5	15	35	-3	7	22	5	20	45
	6	7,5	22,5	50	-3	9	25	10	25	50
	8	2,5	20	42.5	----	----	----	5	22,5	55
50	0,5	0	10	27,5	5	11	21	0	12,5	27,5
Admin: n=226	1	0	10	35	1	8	20	2,5	12,5	37,5
Driller: n=1654	2	5	17,5	40	1	10	29	2,5	17,5	52,5
	3	5	25	47,5	6	20	48	5	25	50
	4	10	27,5	52,5	11	30	58	7,5	27,5	52,5
	6	12,5	32,5	55	15	36	67	12,5	32,5	57,5
	8	7,5	30	57,5	----	----	----	7,5	30	57,5
60	0,5	5	17,5	40	6	13	24	2,5	15	40
Admin: n=51	1	2,5	20	45	2	10	24	2,5	20	50
Driller: n=286	2	7,5	25	57,5	3	15	41	5	28,75	60
	3	5	32,5	60	9	31	56	7,5	37,5	62,5
	4	12,5	35	65	16	41	63	12,5	40	65
	6	12,5	42,5	70	20	47	71	17,5	43,75	75
	8	10	42,5	70	----	----	----	15	45	75

*Age is grouped in 10yr intervals, that is, '30' represents ages 25 to34 yrs, etc.

Table 5-23 Median values for binaural average thresholds across the frequency range for white male participants of the administration (admin) and driller groups categorised by age compared to ANSI S3.44 (1996) Annex C

H.		Median values for hearing threshold dB HL Binaural averages								
MALE, White		Admin			ANSI S3.44 (1996)			Driller		
Age Group *	Frequency (kHz)	(Total n:124)			Annex C			(Total n:46)		
		Percentiles								
		10	50	90	10	50	90	10	50	90
30	0,5	0	5	15	3	9	17	2,5	12,5	25
Admin: n=69	1	0	5	12,5	-1	5	13	0	2,5	12,5
Driller: n=9	2	0	5	15	-4	3	14	0	2,5	12,5
	3	0	7,5	20	-1	6	27	0	7,5	25
	4	2,5	10	22,5	1	12	37	0	7,5	20
	6	5	12,5	32,5	4	17	43	2,5	10	27,5
	8	0	12,5	27,5	----	----	----	0	7,5	22,5
40	0,5	1,25	7,5	23,75	4	10	19	2,5	8,75	17,5
Admin: n=30	1	1,25	5	23,75	0	6	17	0	6,25	15
Driller: n=14	2	2,5	8,75	30	-1	6	20	2,5	8,75	22,5
	3	3,75	12,5	37,5	3	12	38	5	12,5	37,,5
	4	2,5	16,25	47,5	6	21	50	5	23,75	42,5
	6	6,25	17,5	56,25	10	26	58	12,5	28,75	62,5
	8	2,5	13,75	51,25	----	----	----	12,5	20	52,5
50	0,5	5	12,5	32,5	5	11	21	7,5	12,5	35
Admin: n=17	1	5	10	35	1	8	20	2,5	6,25	32,5
Driller: n=16	2	7,5	15	47,5	1	10	29	5	13,75	32,5
	3	5	27,5	62,5	6	20	48	5	17,5	55
	4	7,5	32,5	65	11	30	58	10	17,5	57,5
	6	17,5	63,75	90	15	36	67	5	30	62,5
	8	20	30	65	----	----	----	10	33,75	70
60	0,5	5	13,75	65	6	13	24	5	25	54,5
Admin: n=8	1	5	13,75	52,5	2	10	24	7,5	15	54,5
Driller: n=7	2	7,5	25	72,5	3	15	41	2,5	15	62
	3	15	50	75	9	31	56	5	27.5	64,5
	4	20	55	82,5	16	41	63	7,5	32.5	64,5
	6	30	63,75	90	20	47	71	15	52.5	67
	8	27,5	57,5	87,5	----	----	----	12,5	57.5	70

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

5.6. Sub aim 5: To evaluate the effectiveness of the current impairment criteria to identify NIHL and compare it to other existing criteria

In South Africa compensation is based on the definition of hearing impairment as defined in the guideline from the RSA Compensation Commissioner, Instruction 171 (RSA Department of Labour, 2001). Instruction 171 introduced a measure of impairment termed percentage loss of hearing (PLH) which is calculated by using a series of tables based on a summation of hearing loss in each ear at the following frequencies: 500, 1 000, 2 000, 3 000 and 4 000 Hz (RSA department of Labour, 2001). Apart from calculation with Instruction 171, the other methods use a five: one favouring the better ear, and a 25dB HL low fence (Dobie, 2001). One such widely-used method to calculate hearing impairment (most American states use or permit its use) is the AMA (1979) method (Dobie, 1992; AAA, 2003; AMA, 1955). Dobie (2001) discussed in detail evidence that supports the use of the AMA method to appraise the effect of hearing loss in everyday life. The AMA method calculates a percentage hearing impairment as follows: From the pure-tone average (PTA) threshold for 0,5, 1, 2, and 3 kHz (PTA5123), a monaural hearing impairment (MHI) score is calculated: MHI (%)= 1,5 (PTA5123 – 25). The range of MHI is 0 to 100%. When hearing is symmetrical, MHI and the binaural hearing impairment (BHI) are identical, but when there is asymmetry, BHI is a weighted average of the right and left ear MHI scores, favouring the better ear (5:1) (American Medical Association (AMA), 2001).

Using the PLH calculations results were divided into different PLH categories namely PLH 5 (PLH values between 0-5 %), PLH 10 (6-10%), PLH 15 (11-15%), PLH 20 (16-20%), PLH 25 (21-25%), PLH 50 (26-50%), PLH 100 (51-100%). The AMA formula was used to calculate AMA values for each participant. For each of the different PLH categories mean AMA values were calculated and are shown in figure 5.25. The comparison aimed to show whether values of the PLH compared to the AMA are similar or not. If values are similar, the AMA mean should be included in the category values, for example within category PLH 5-10, a similar AMA value would be between 5 and 10 dB. A red circle indicated where these categories did not overlap with the AMA means.

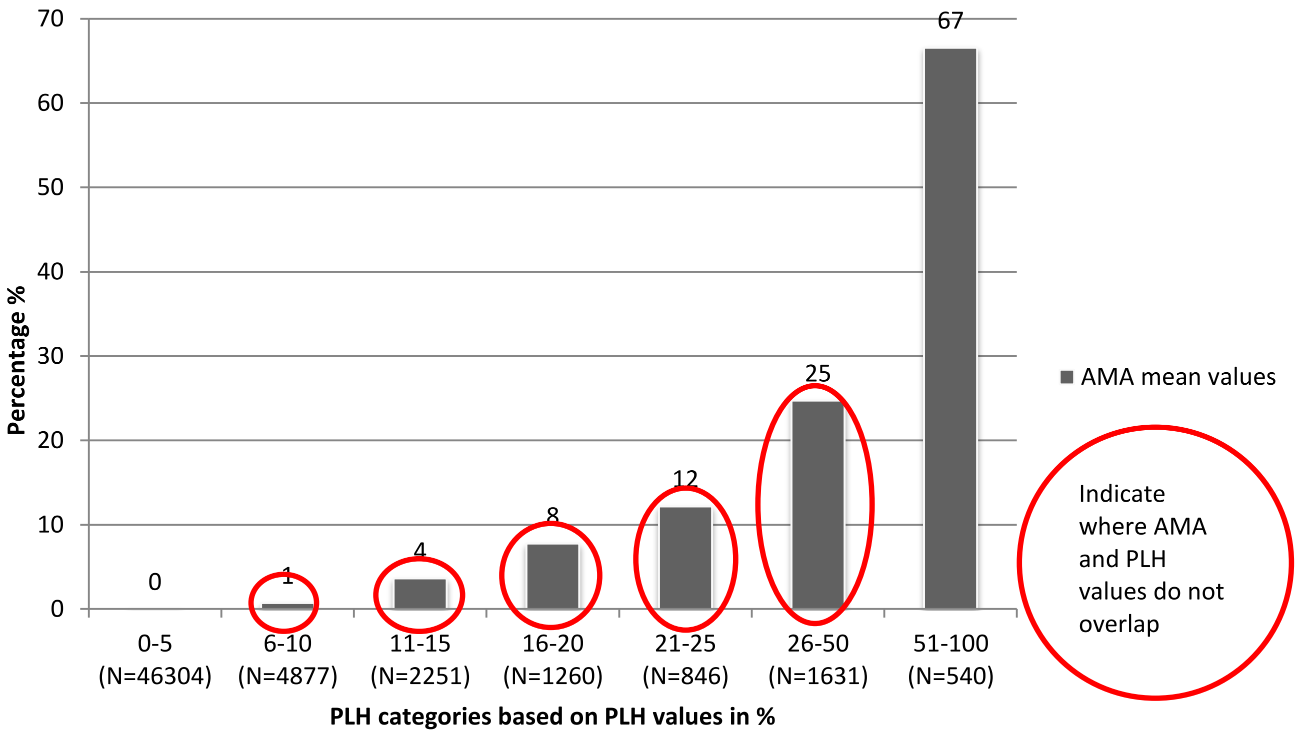


Figure 5-24 Mean values for binaural hearing impairment calculated using the AMA formula for participants in the different PLH groups. PLH groups based on the PLH values in percentage calculated for all participants (N=57691)

From figure 5.24 it appears that the means of the AMA calculations were mostly (with the exception of the PLH 51-100% group) lower than the associated PLH values. For example, in the PLH group with PLH values between 16 and 20% the associated AMA mean was 8%. Only for the PLH group with normal hearing and the most severe hearing impairments (based on PLH values) did the AMA averages overlap with the PLH values. These results were based on AMA values for the specific PLH category. Subsequently AMA values were evaluated independently and compared to PLH values in terms of compensation.

Based on the guidelines from Instruction 171 (COIDA, 2001) a person has a hearing impairment compensable under law when a 10% shift in PLH from baseline is present. The assumption can be made that the lowest PLH indicating compensable hearing impairment is 10%. With the AMA any loss constituting more than 0% hearing impairment is defined as compensable hearing loss.

In order to compare compensable hearing impairment based on the different formulae the minimum required hearing impairment for compensation was calculated. The number of participants in the PLH≥10% and AMA >0% were calculated and compared. Results are shown in figure 5.25.

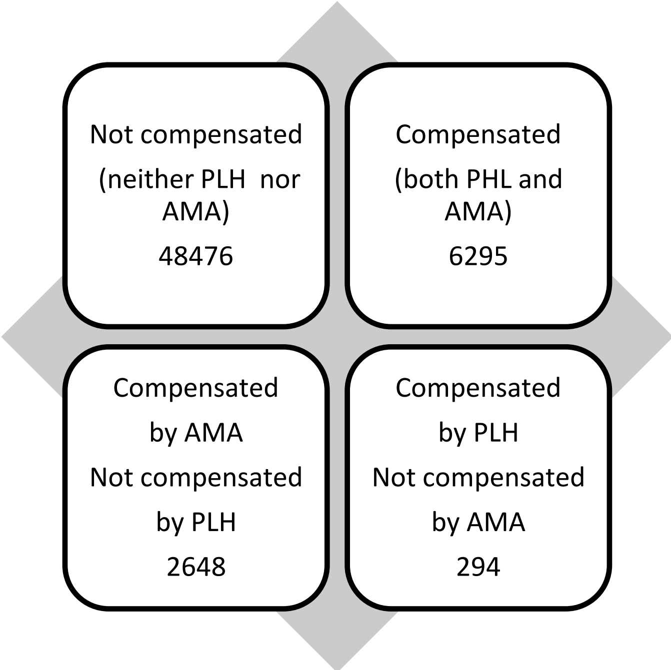


Figure 5-25 Comparison of numbers of participants (total N=57713) who would have been compensated based on the hearing impairment comparing the PLH and AMA formulae of hearing impairment

From figure 5.25 it is clear that the majority of participants in the cohort did not have a compensable hearing impairment. These participants were followed in numbers by participants whose hearing impairment was of sufficient degree to have been compensated if either formula was used. A large number of participants (2 648) revealed a hearing impairment that would have been compensated if the AMA formula but not the PLH formula was used. When using the calculations of the PLH method only 295 participants that did not show a significant hearing impairment (compensable) would have been compensated based on the calculation of the AMA formula.

5.7. Chapter summary

This chapter provided a presentation of the results obtained in the empirical study. This included qualitative data with inferential statistics presented according to the sub aims specified for this study aiming to address the main aim of the study.