Reconstruction of percentage loss of hearing

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ABSTRACT

Percentage Loss of Hearing (PLH) is used in South Africa to establish a baseline audiogram for employees exposed to noise in the workplace. This baseline audiogram is valid for a worker's entire working career and serves as a reference point from which PLH-shifts are determined for purposes of hearing conservation and compensation for noise-induced hearing loss (NIHL). The PLH should, for these reasons, be determined as accurately possible. This study revisited the current baseline audiogram, with the recommendation that it be replaced with the B-baseline audiogram, which is more representative of workers' true hearing thresholds (HTs). South Africa adopted and adapted the current method of calculating PLH from Australia, where it was developed by the National Acoustic Laboratory. The findings from this study might benefit both South Africa and Australia, as well as other countries not currently using baseline audiograms.

Keywords: **noise-induced hearing loss, baseline audiometry, B-baseline audiometry, PLH procedure, industrial audiometry**

INTRODUCTION

Noise-induced hearing loss

Noise-induced hearing loss (NIHL) in South Africa accounted for 68.4% of all successful claims for occupational related diseases (ORDs) during the 2005/6 – 2007/8 financial years.[1] The loss in monetary terms relating to NIHL claims was not officially published by the Compensation Commissioner in the annual reports for these respective years, but it is estimated at approximately R276 million.[1,2]

Air conduction audiometry

The hearing status of employees exposed to noise is monitored with the use of audiometry tests. Audiometry results are determined when a person responds to an audible perception of a stimulus – in this instance, a pure tone. Currently in South Africa, seven pure tones are used when audiograms are established, namely 0.5, 1, 2, 3, 4, 6 and 8 kHz. Each stimulus is presented through earphones to the person, and the medium through which the stimulus is conducted from the earphones through the outer and middle to the inner ear is air, hence the term 'air conduction' audiometry testing.[3] When audiometry tests are done correctly under predetermined conditions, with the use of equipment as specified by South African standards,[4-6] a response should not be noted in the absence of sensory perception. A pure tone with the lowest intensity at which the person responded to indicate audible perception, is considered to be the hearing threshold (HT).[3] The recorded air conduction audiometry results (or HTs) can therefore only be equal to, or higher than, the actual HT level of a test subject.[2]

Audiometry results used for hearing conservation

The audiometry results are used for purposes of both hearing conservation and determining cases where compensation for NIHL should be considered. Historically, different methods were used for these two purposes.[2]

For hearing conservation purposes, the South African Bureau of Standards (SABS) 083-1962 referred to "hearing loss" without quantifying it and by comparing loss in hearing of a test subject to "accepted normal threshold of auditory sensation".[7] SABS 083:1970 referred to "Impairment of hearing" which was defined as "a threshold shift of more than 25 dB derived from the arithmetic averages of the HT values of the test subject measured at 500 Hz, 1000 Hz and 2000 Hz".[8] SABS 083:1983 renamed it "Hearing impairment".[9] The Referral Threshold Shift (RTS) was used from 1996 until 2012[10] "solely to monitor the efficacy of hearing conservation programmes".[10] An RTS was described as a deviation for the worse in the HT (from that first ever recorded) at any of the seven test frequencies. An RTS would have existed if the deviation was >15 dB or >20 dB over periods of a year or 20 months, respectively.

Audiometry results used for purposes of compensation

From January 1995 to November 2003, Percentage Binaural Impairment (PBI) was used in South Africa in accordance with Instruction 168, to quantify NIHL for compensation consideration.[11] PBI was a cumbersome procedure to determine hearing impairment relating to the workplace, and HTs at

four frequencies, namely 0.5, 1, 2 and 3 kHz, were used. During this procedure, distinction was (and still is) made between HTs for the worse and better ear. A shortcoming of this method was that hearing impairment at 4 kHz, the first frequency likely to show an increase in HT following noise exposure, was not taken into account when considering compensation.[11]

Instruction 171, published and later supplemented in Government Gazettes dated 16 May 2001[8] and 16 November 2001, respectively, changed the procedure used for calculating NIHL for compensation consideration from PBI to Percentage Loss of Hearing (PLH).[12,13] This instruction prescribed a different method for monitoring hearing status through PLH shifts and dictated that a baseline audiogram had to be established for each employee to be used for future purposes of compensation.[12,13]

Percentage loss of hearing

PLH is a value that is not, as its name suggests, used soley to indicate hearing loss. The PLH is calculated with the use of measured HTs and a baseline audiogram is assigned, based on this value. As the calculated PLH cannot be lower than 1,1%, even with HTs equal to or less than 0 dB, the PLH does not necessarily indicate hearing loss. Rather, it is a reference value for the hearing status of an individual against which loss can be measured.

The baseline audiogram currently used in South Africa to monitor the HT of employees exposed to noise is based on the 'better' of two tests conducted on the same day.[12,13] Prior to testing, it is required that the employee not be exposed to noise equal to or in excess of the noise rating limit for hearing conservation [85 dB(A)] for a minimum period of 16 hours (rest period).[13] The use of personal hearing protectors is not permissible as a means to comply with this rest period.[12] For each ear, the HTs are compared at 0.5, 1, 2, 3 and 4 kHz. If the difference between the HTs at each of these frequencies does not exceed 10 decibels, the HTs are regarded as reliable and are then used to calculate the PLH to determine the baseline audiogram.[13]

An example of two audiometric tests used to determine a baseline audiogram, including the PLH values, is given in Figure 1. The PLH is calculated separately for each of the two tests, using five frequency-specific tables that are published in Instruction 171.[12] Using the HTs of the better and the worse ear, the contributions to the PLH are read from these tables for each of the five frequencies (0.5, 1, 2, 3 and 4 kHz). The sum of these five contributions serve as the PLH of the test.[12] Once the PLHs have been calculated

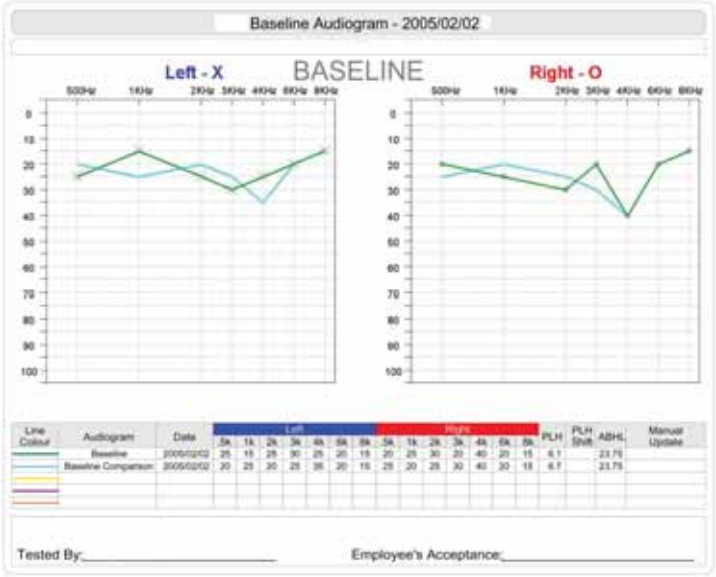

Figure 1. Example of two audiometric tests used to determine a baseline audiogram, including the PLH values

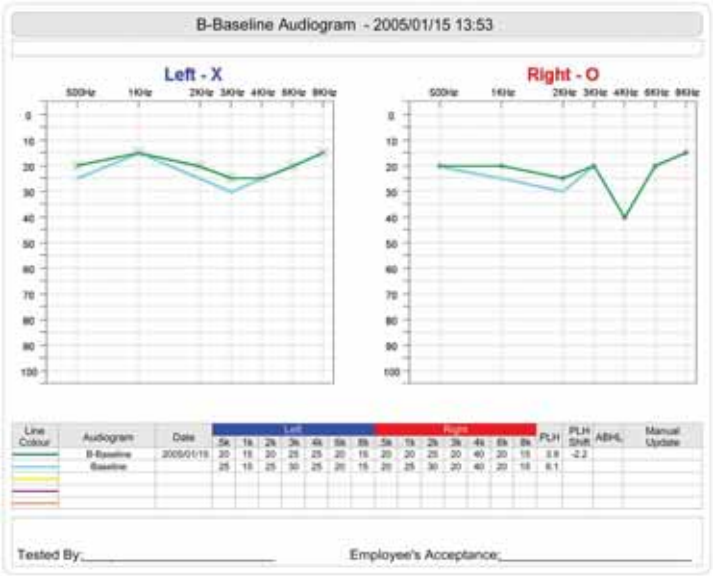

Figure 2. Example of the proposed B-baseline audiogram created by using the lowest HTs of the two tests depicted in Figure 1 (note the PLH values)

for both tests, the test with the lowest PLH is taken to be the baseline audiogram, and is applicable for the remainder of the person's working career.[13] As all future audiograms will be compared to the baseline audiogram to monitor the HTs of a worker for both hearing conservation and compensation purposes, it follows that the PLH should be determined with utmost accuracy.

HTs shifts for conservation[4] and compensation purposes[13] are quantified by the increase in the PLH, referred to as a PLH-shift.[4] The baseline audiogram's PLH is deducted from that of the routine screening audiometry test to determine a PLH-shift – referred to in SANS 10083 as a "possible PLH-shift".[4] For purposes of compensation, diagnostic baseline audiometry testing is required[12] should a possible PLH-shift of >10% be calculated.[4] This is done by an audiologist and requires a 24-hour rest period prior to testing.[4] Reliability of the diagnostic baseline is determined, using the same principles as applied during routine baseline audiometry.[12] The diagnostic baseline audiogram's PLH is deducted from the baseline audiogram's PLH to establish the PLH-shift.[4] A (confirmed) PLH-shift of >10% requires an occupational medical practitioner or otorhinolaryngologist to determine the cause for the loss.[4,12] If the hearing loss is found to relate to the work place, it should be reported to the Compensation Commissioner or, in the case of the mining industry, to the applicable insurance fund for compensation consideration.[4,12]

Based on the importance of the PLH as a tool for hearing conservation and compensation, the objective of this study was to investigate if the accuracy of the current method for determining the baseline PLH can be improved. As the HTs determine the PLH, it was hypothesised that using only the lowest of the measured HTs to calculate the PLH, rather than the HTs of the better and the worse ear (for each of the two tests), will result in a new baseline audiogram with a more accurate PLH.

METHODS

For the current procedure for determining the baseline audiogram, the measured HTs of the two audiograms are considered to be absolute threshold datasets. Since these datasets are used individually to determine the PLH for each test, the probability exists that the lowest HT for some of the pure tones will not be included when calculating the PLH of the baseline audiogram and, when using the higher HTs, would possibly result in higher baseline PLHs. For this reason, a different method was proposed to establish a new more accurate baseline audiogram, named the B-baseline audiogram.

The baseline audiograms of 1101 employees, working in a variety of industries located in the Western Cape, South Africa, and conducted during the period November 2001 to November 2007, were analysed. The database was stripped of all variables that could identify companies or employees. All audiometry tests in the database were conducted in accordance with South African standards, by registered audiometrists.[3-6] The audiometers used were electro-acoustically calibrated and testing environments were certified to be compliant with South African standards.[5,6]

B-baseline construction

By selecting the lowest HT for each ear at the PLH frequencies of 0.5, 1, 2, 3 and 4 kHz from the two audiograms available – a third audiogram, the B-baseline audiogram, was created, using Everest audiometry software.

The PLHs of the proposed B-baseline audiograms were compared with those of the recorded baselines using the

Students t-test for dependant samples. StatSoft Statistica software (version 9.1) was used for the analysis.

RESULTS

To determine the effect of the proposed B-baseline procedure on the PLH, it was necessary to omit all employees with normal HTs from the database. It was argued that, if cases with normal HTs which could not be 'improved' (and which would render a PLH of 1,1%) if the current methodology of calculating the PLH was employed) were retained in the database, this would dilute or mask the findings of the study. Thus, the audiometric results of 545 employees with normal hearing were omitted from the database. The remaining 556 employees' results were included in the statistical analysis.

For 190 (34.2%) of the 556 audiometric results analysed (where a PLH decrease was possible), the B-baseline provided a statistically significant ($p<0.001$) lower PLH than the baseline, which is indicative of more accurate PLH determination (see Table 1).

Figure 2 illustrates the creation of the B-baseline audiogram, using the lowest HTs of the two tests depicted in Figure 1. In this example, the lower HTs used to construct the B-baseline resulted in a PLH of 3.9% versus 6.1% which was calculated using the baseline audiogram, i.e. a difference of 2.2%.

DISCUSSION

It has been proven that over-exposure to noise can result in permanent sensory-neural hearing loss, known as NIHL.[14] As NIHL is preventable[15], it is imperative that hearing conservation measures be taken. Although South African standards stipulate that hearing conservation measures should be taken in workplaces where the noise rating limit (LReq,8h) for hearing conservation is exceeded[4,16], statistics from the Department of Labour indicated that, during the period of this study, 68.4% of all ORDs were related to noise.[1]

B-baseline audiogram and hearing conservation

In instances where PLH-shifts of 3.2% or 6.4% are determined, SANS 10083:2012 provides for intervention or advanced intervention, respectively, to mitigate the increase of PLH-shifts.[4] As the B-baseline utilises the lowest and most accurate HT to determine the PLH, it is anticipated that deteriorations in the HTs and consequent PLH-shifts will be detected earlier. This will identify those employees who are at risk for developing NIHL early enough to ensure effective intervention. Timely intervention protects the interests of both the employer and the employee.

Table 1. Results of t-test for dependant samples (baseline and B-baseline audiograms) for audiometric tests where PLH could be improved (n=556)

Variable	Mean	Difference	95% CIs	p-value
Baseline	4.220			
B-baseline	4.097	-0.123	-0.099, -0.147	<0.001

B-baseline audiogram and compensation

As the Compensation Commissioner uses the baseline PLH to determine PLH-shifts for purposes of compensation for NIHL, the more accurate B-baseline audiogram should assure employers that are financially affected by successful claims for NIHL that referrals and compensation decisions are based on more accurate calculations.

B-baseline audiogram and diagnostic testing

An important consideration to note is that, should the B-baseline be adopted for screening audiometry, it should also be adopted for diagnostic baseline audiometry. If the same procedure is not implemented when calculating the screening and diagnostic baseline PLH, it is possible that the diagnostic audiometry could show an inaccurate PLH-shift, resulting in an increase in the number of cases qualifying for compensation consideration. This would defeat the purpose of a more accurate B-baseline.

Feasibility of implementing the B-baseline audiogram

Implementation of the B-baseline audiogram is anticipated to be both time- and cost-effective. Constructing a B-baseline audiogram and calculating the PLH would be possible with the use of existing data and no additional tests would be required to render more accurate results. Furthermore, affordable audiometry software is readily available and used in South Africa to process audiometric test results. The existing software could be easily adapted and updated to incorporate the B-baseline procedure.

The B-baseline audiogram methodology is not limited to South African use but may also be of benefit to other countries where audiometric testing is done for purposes of hearing conservation. The advantage of determining a baseline audiogram offers the accuracy feature as described, and using the B-baseline audiogram provides for more accurate results. These advantages can be utilised in audiometry by using the lowest HTs – even if the PLH procedure is not used.

CONCLUSION

Audiometry results should be as accurate as possible as they are used to monitor the hearing status of those exposed to excessive noise as well as to evaluate the effectiveness of hearing conservation programmes. Inaccurate audiometry test results could impede interventions to prevent progressive hearing loss or lead to unnecessary referrals and expenditure. Practitioners should therefore use methodologies based on a PLH-shift to prevent noise-induced hearing loss (PLH-related intervention measures are stipulated in SANS 10083:2012). The B-baseline audiogram provides a more accurate audiometry result (HTs) than the baseline method that is currently used.

LESSONS LEARNED

- HTs, measured at baseline, are used to calculate the baseline PLH which is used to determine subsequent loss of hearing and, potentially, compensation for NIHL.
- The current method of determining the baseline audiogram results in an inaccurate summary HT that is higher than the 'real' HT.
- The B-baseline audiogram method provides a more accurate baseline audiogram for workers.
- The B-baseline audiogram method can be used even in situations and countries where PLH is not used, for establishing accurate baseline HTs.

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