Test of hearing loss and hearing impairment in employees complaining of noise annoyance

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INTRODUCTION

Complaints of noise annoyance are increasing in several areas of the working environment, particularly in open offices, schools and kindergartens. The noise levels seldom reach noise levels with risk of noise induced hearing loss, but the cause emerges from a complex interplay between the level and the character of the noise, the acoustics of the workplace, psychosocial stress-factors, and individual factors including hearing ability. Among the main problems are the acoustic quality of the rooms, and the hearing ability of the employees. With longer life expectancy and a change towards service jobs with high communicative and high cognitive demands, it is important that the working environment does not exclude employees with reduced hearing abilities, who have great difficulties in hearing in noisy surroundings of low acoustic quality. Another trend in hearing ability is reduced hearing among adolescence, which seems to be serious with the expectancy of a longer working life. Regular tests of hearing thresholds in noise exposed employees are required all over the world, but the audiogram may not determine minor deficits in hearing or initial signs of noise induced hearing loss (Attias et al. 2001; Torre et al. 2007). Oto-acoustic emissions (Job et al. 2007) and suppression of oto-acoustic emissions (Zhang et al. 2007) may be a valuable tool in measuring the plasticity of hearing, but further validation is needed. If a greater number of subjects have to be tested, it is also necessary to introduce time optimized protocols (Sisto et al. 2007). We have tested these methods in a binaural setup, and will present a series of decisions, which has to be made in order to do assessments in the field.

METHODS

Hearing thresholds and oto-acoustic emissions were tested on military officers (n=51, aged 21-63 years from a Danish telegraph regiment. Otoscopic examination and 226-Hz probe tone tympanometry (Madsen Zodiak 901) were used to screen participants before the tests of hearing. Distortion product oto-acoustic emissions (DPOAE) were performed bi-aurally with two identical DSP-systems from Tucker-Davis Technologies (TDT, Alchua, FL) and two Ethymotic Research (ER, Elk Grove Village, IL) microphone probe systems (ER10B+ connected by tubes to ER2 sound transducers). Two 24-bit RX6 Piranha DSP-processors were generating simultaneous in- and output (8192 samples) at 24,414 Hz. The output level was controlled by four programmable attenuators (TDT PA5) driving each of the sound transducers according to drive specifications of the transducers (100 dB SPL at 1 Vrms). The balance of four transducers was equalized in a 2 cc coupler (B&K DB0138) towards a ½" pressure-field microphone (B&K 4192) and a HP35670A analyzer. The input from the ER10B microphone drivers were amplified 30 dB (TDT MA3 microphone amplifiers) before filtering (sigma-delta) and A/D-conversion by the DSP-processors, using the supplied calibration curves of the microphones. The data were collected from the DSP-processors by a fiber optic interface (TDT Gigabit Interface), analyzed and controlled by computer using TDT ActiveX modules, Agilent VEE 7.0, and MATLAB. The

DPOAE assessments on each ear consisted of six DP-grams with measurements of the cubic distortion product (CDP= 2f1-f2) from 32 sets of primary input tones (f2/f2=1.23; f2 ranging from 707 Hz to 10,374 Hz) and 8 repeated time series averaged for each set of primaries. The six DP-grams were obtained at five different levels of the primaries (L2= 45 dB, 50 dB, 55 dB, 60 dB, 65 dB, and 55dB SPL; L1= L2+10 dB). The background noise level across frequencies at each level of stimulation was determined by calculation of the average response of all the measurements, where the primaries were not generating a specific response at the frequency of the CDP measurement. Single frequencies with high level of both CDP and background noise due to swallowing or movements were redone at the end of each DP-gram assessment. The same setup and probe systems was used for assessments of audiograms with automatic threshold determination (125.2 Hz, 250.3 Hz, 500.7 Hz, 1001 Hz, 1541 Hz, 2000 Hz, 3085 Hz, 3999 Hz, 6169 Hz, and 7999 Hz; 1 kHz upwards, 1 kHz downwards) in 5 dB steps. The input from each microphone was tested regularly in a B&K 4230 sound level calibrator. All tests of hearing were performed in a transportable sound booth (IAC 250 Sound Shelter, complying with ISO 6189). Before measurements of either hearing thresholds or oto-acoustic emissions, proper fitting of the earplugs was tested by measurement of the output from each transducer in situ at 500 Hz.

RESULTS

The tests of each individual including otoscopic examination and tympanometry was planned to be performed within an hour and up to 8 persons per day. However, this proved to be a problem because the output from the ER 10B microphones dropped during continued use. This turned out to be caused by substantial sensitivity to high relative humidity, which increased the variation of the results and seriously disturbed the intentions of the study. However, of the 51 officers participating in the study, only three individuals were left out because of technical difficulties. The rest (48) was divided in quartiles on the basis of the average 1-8 kHz hearing thresholds on the right ear, and the audiograms and DP-grams of left ear and right ears from the four quartiles are shown in Figure 1 and Figure 2. Both the audiograms and the DP-grams show initial impairment at 1.5 to 4 kHz, and again above 4 kHz, which may be related to impulse noise exposure from small firearms. With increased hearing thresholds the amplitude of the CDP and the steepness of the IO-functions changes on both ears. Where the DP-grams with increasing stimulation (L2 from 45 to 65 dB SPL) lie close together, the growth of input-output function (IO-function) shows the normal compressive function of the Basilar Membrane (Moore 1998), but even with small changes in hearing thresholds, the shape of the IO-function changes to a more steep increase with the increase in stimulation.

DISCUSSION

Measuring small changes in hearing thresholds is a laborious task, being in nature a testing of a signal to noise ratio. Proper testing demands low background noise level and may be time consuming. If one wishes to introduce a new test of hearing ability, the total time cannot be extended of testing very much, because the salaries of the

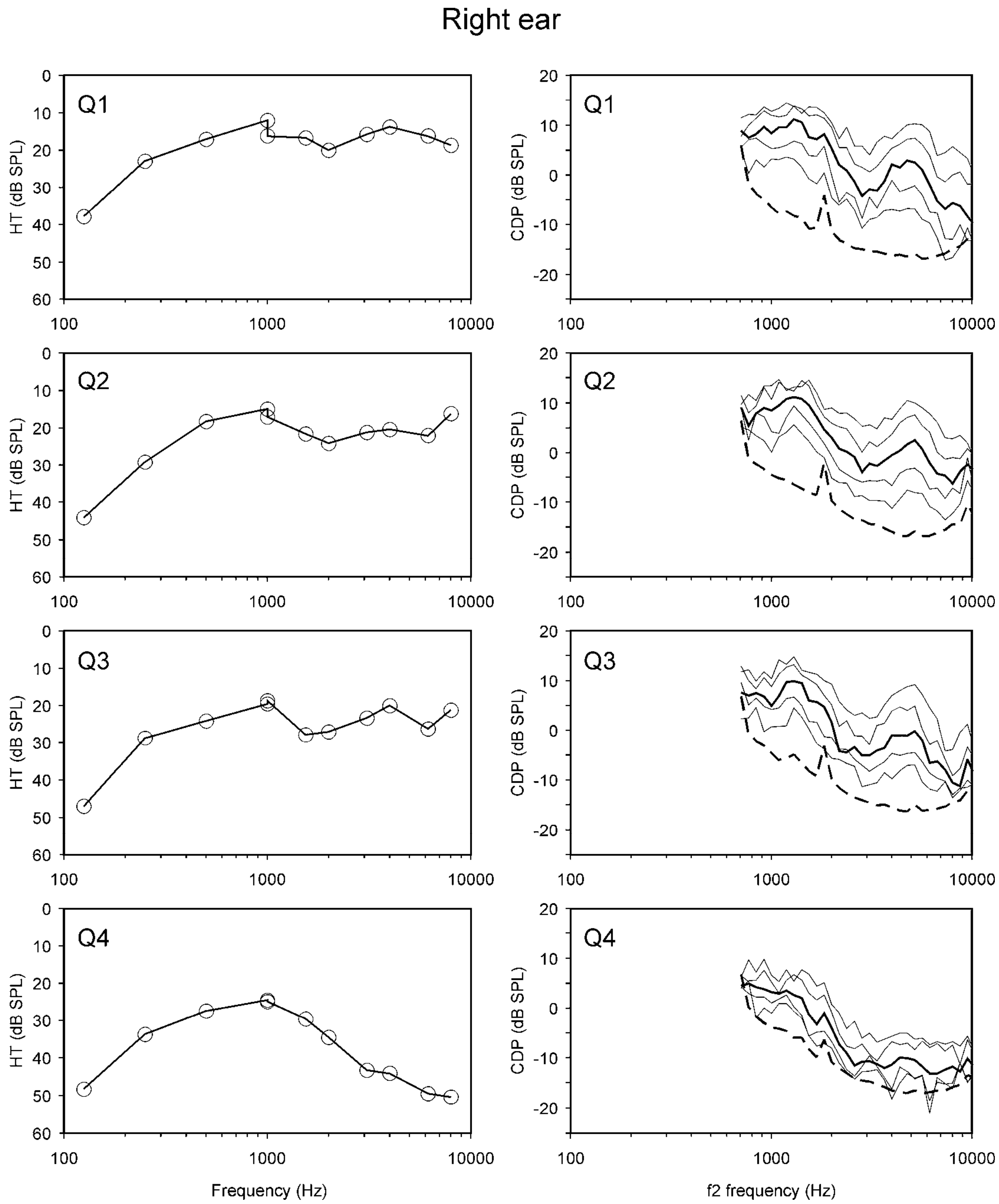

Figure 1: Right ear audiograms (Left: Hearing thresholds, HT) and DP-grams (Right: Cubic Distortions Products, CDP) of 48 male officers, divided in 4 quartiles on the basis of right ear average hearing thresholds from 1-8 kHz. The DP-grams are made with L2 primary levels from 45 to 65 dB SPL, the thick line being the average between two measurements at L2= 55 dB SPL. The dotted line is the average background noise level without primaries.

participants has to be paid, either by their employer, the participants themselves, or financed by the study. Using longer time of testing may often decrease the number of participants, which does make it difficult to study more subtle risk factors of hearing impairment. Oto-acoustic emissions has potential to study both subtle hearing loss as well as the some of the dynamic parameters of hearing, which may be very valuable in assessing noise sensitivity and future demands to acoustic quality, as well as testing for early signs of noise induced hearing loss. At present time, no such system seems be commercially available, but the current price of DSP-processors and computer power no longer inhibits the acquisition of systems with sufficient capacity to

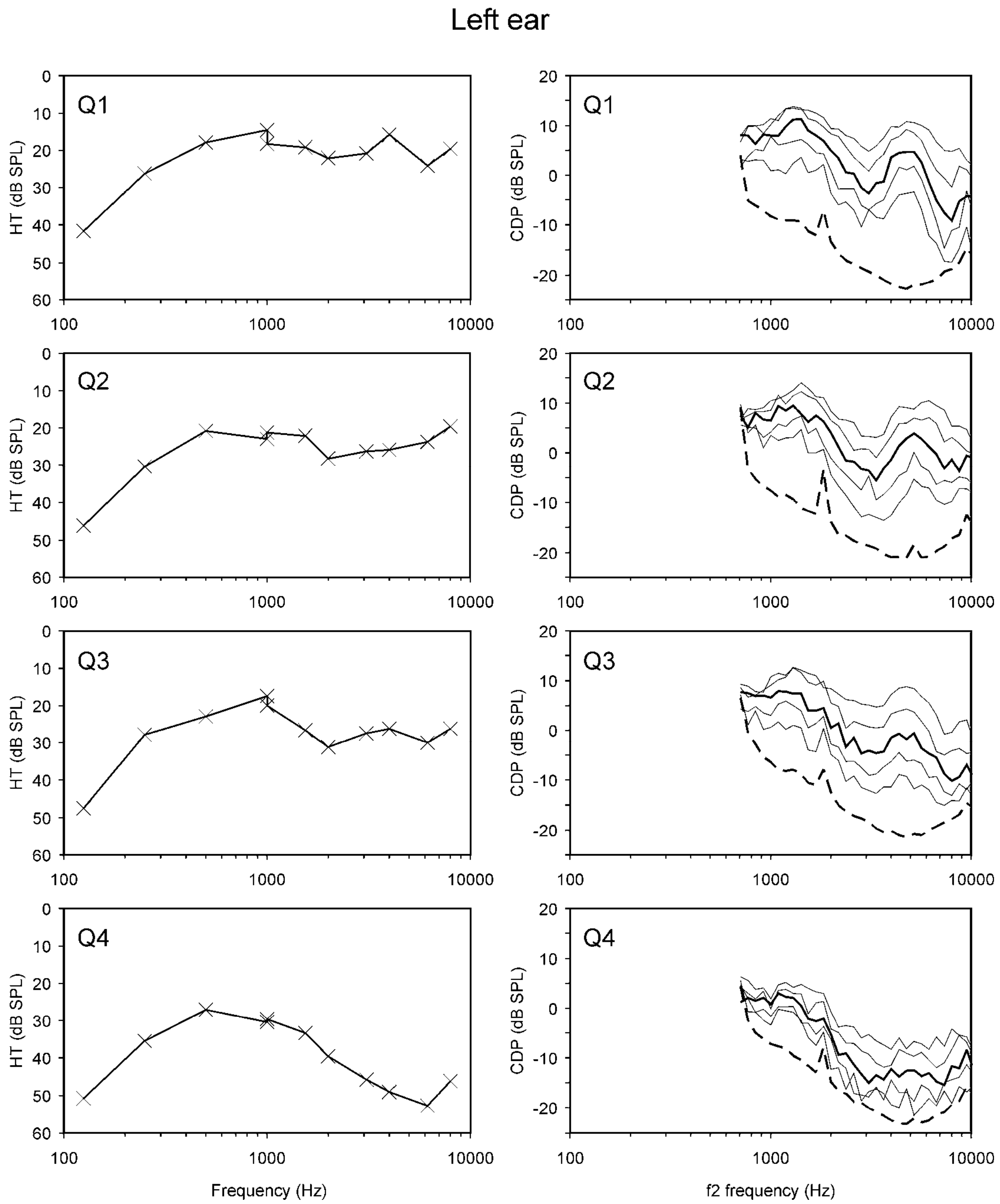

Figure 2: Left ear audiograms (Left: Hearing thresholds, HT) and DP-grams (Right: Cubic Distortions Products, CDP) of 48 male officers, divided in 4 quartiles on the basis of right ear average hearing thresholds from 1-8 kHz. The DP-grams are made with L2 primary levels from 45 to 65 dB SPL, the thick line being the average between two measurements at L2= 55 dB SPL. The dotted line is the average background noise level without primaries.

make the assessments in real time. The main problem is to design and validate a system for extended use, which is fast, robust and easy to use. The assessments of one DP-gram with the present system takes approximately 90 seconds, and often one or several frequencies has to be redone because of swallowing or head movements, increasing the time of one DP-gram to about 2 min. In order to test the efferent system (the medial olivocochlear reflex) by contra-lateral suppression oto-acoustic emissions, a bi-aural system is preferable, but that also necessitates calibration and balancing between left and right probe system. Further, using low primary stimulus levels requires low background noise levels or averaging number of recordings as time series, and the latter certainly increases the total time of testing across many frequencies and several stimulus levels (IO-curves). The better signal to noise ratio is in favor of measurements at higher levels of the primaries, but as seen on the DP-grams in Figure 1 and Figure 2, the high stimulus levels reveal less information of the actual status of the cochlear amplifier along the basilar membrane. Therefore it should be performed at reasonable levels of primaries to yield a CDP response before the top of the IO-curve and well above the noise floor, and the optimum seems to lie at L2 ~50-55 dB SPL.

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