

## Hearing assessment of students of a music conservatoire using otoacoustic emissions

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### ABSTRACT

Since the introduction of the UK's Control of Noise at Work Regulations research has been undertaken in collaboration with the Royal Academy of Music investigating the hearing acuity of their classical music students. Since 2007 more than 5000 students have been assessment using audiometry based health surveillance. Due to COVID pure tone audiometry was no longer safe to undertake, July 2021, so a new approach was taken using otoacoustic emissions. Since 2021 502 musicians have had their otoacoustic emissions assessed using Hearing Coach software / firmware. The results have been used to independently test the Hearing Coach dataset in terms of hearing acuity and has produced a simple rule of thumb to engage the public in the understanding of their hearing acuity. Results show that identifying an objective criterion which illustrates, "Having young ears" is very easily and quickly understood by the students. This provides reassurance that otoacoustic emissions is an excellent supplementary tool for assessing the hearing health of students from a music conservatoire.

Keywords (3-6): Otoacoustic, Musicians, Music, Hearing, Audiometry

### INTRODUCTION

The Control of Noise at Work Regulations 2005 (CoNAWR2005) [1] was introduced in the UK to protect employees from health risks associated with noise. The Regulations were put in place in 2006 for all sectors other than the entertainment sector who were allowed an additional 2-year transitional period. With regards to sound exposure, it is known that excessive exposure results in Noise Induced Hearing Loss (NIHL) typically at 4 kHz [2]. Approximately half of NIHL occurs within the first 3 years of excessive sound exposure with the remaining NIHL occurring over the following 42 years [3,4]. Therefore, it is critically important to protect new employees at the earliest opportunity. The CoNAWR was a result of research into the effects of occupational noise exposure

on hearing health, all of which were based on industrial environments and hence did not include effects of entertainment sound or music exposure. This was likely a result of the absence of relevant data. However, recently there has been some research investigating this field of study [5-7]. In addition, enforcing the regulations on the entertainment sector is particularly difficult due to the nature of their work and sound being a deliberate product. Recently, the Royal Opera House lost a High Court case based on a musician suffering from acoustic shock [8].

Since 2007, through a long-term collaboration with the Royal Academy of Music (RAM), approximately 330 students each year have been assessed using automated audiometric based screening based on pure tone audiometric (PTA) to determine hearing acuity [9]. Now, a new hearing assessment method is being trailed in a parallel study that meets the CoNAWR assessment criteria, this time based on Otoacoustic Emissions.

## **MUSICIAN BASED HEARING RESEARCH**

Otoacoustic Emissions (OAE) based hearing assessments have been used to test the hearing acuity of new-born babies. It has been shown that a reduced OAE amplitude is a precursor to NIHL and hence may act as a biomarker for susceptibility to NIHL [10]. In 2008, a comparative study was carried out using 154 young adults (aged 18-25) regularly exposed to occupational noise and 99 non-exposed (of same age group) and their hearing was assessed over a 3-year period using pure tone audiometry and Transient-Evoked OAEs (TEOAE). The young adults of both groups are likely to have also been exposed to social noise, personal music players, live events, and nightclubs. Results showed that the hearing threshold values, an average across the frequencies of 3, 4, 6 kHz, of the exposed group were 1.7 dB worse compared to that of the non-exposed group whereas, according to the ISO 1999 methodology [3], a 6 dB reduction was predicted based on cumulative amount of occupational and social noise exposure [11]. The difference between the measured and predicted threshold shift, 270%, could not be due to misremembering the number of social events attended, or the length of time listening to personal music players. Hence, it can be reasonably inferred that social noise exposure and music has a different effect on hearing than occupational noise of equivalent noise energy. This agrees with the results of the conservatoire-based studies focused on the effect of the sound of performance on the hearing of classical musicians [7,8]. The 2008 report by Lutman, Davis and Ferguson concluded, "OAE may be beneficial to supplement PTA, as audiometry has limited sensitivity to detect Noise Induced Hearing Loss, 15 dBHL is required before confidence can be attached to the change in individuals. Future research may show that PTA and OAE have complimentary roles." [10].

In November 2019, Transient Evoked / Distortion Product OAE based hearing screening was trailed by audiologists employed by the Royal College of Music (RCM). In total 80 classical music students were assessed over a two-week period. The results of which informed the recently introduced British Association of Performance Arts Medicine (BAPAM) Best Practice Guidance [12]. OAE have very recently been approved for clinical use by the British Society of Audiology with the introduction of a recommended procedure for OAE based assessment [13]. The authors decided that the same OAE testing methodology as used by RCM would be used to further assess hearing of the Royal Academy of Music students supplementing the automated audiometric screening as part of their health surveillance programme. This change of approach was necessitated by COVID as the only safe test methodology that could be undertaken during the pandemic. As such the 2020/21 students only undertook an OAE based assessment as this does not require an ISO 8253-1 compliant sound-proof booth [14].

## PILOT STUDY

A study of 587 classical music students was undertaken over a two-year period starting in July 2021 [15,16]. The hearing conservation programme commenced with a one-hour virtual seminar on risks to hearing associated with the sound of music performance. The hearing assessment itself consisted of a short questionnaire, completed as a one-to-one interview, which included information on instrument studied and years of music exposure plus additional information on leisure activities, part-time work, and music listening habits. Each student was allocated a 15-minute slot for the hearing assessment comprising OAE and PTA. OAE testing was undertaken in an anechoic chamber, ambient noise level LAeq, 30 minutes 18 dBA, using a Path Medical OAE Senti instrument and dual ear probes with eight sizes of ear tips to ensure a good ear canal seal [17]. The instrument was used in simultaneous ear mode to speed up the testing procedure, so that an assessment could be undertaken in under three minutes. The anechoic chamber was also found to speed up the assessment due to lower ambient noise levels. In addition those students with excellent hearing acuity were found to complete the test in less than 1 minute. Hearing Coach software [18] was used to analysis the OAEs to produce Estimated Outer Haircell (OHC) Damage percentage at twelve frequencies, 1000-6500 Hz at 500 Hz intervals for each ear and an overall estimate of OHC damage. The results were then explained to the student with a proposed new rule of thumb, “damage less than the patient’s age indicates good hearing acuity”. This paper tests that hypothesis which was create for reasons of simplicity of understanding and speed of explanation.

## PRIOR RESULTS

In March 2022, after discussions with Hearing Coach [19] evidence was provided, see below, as to the OHC damage by age and gender based on 30,000 tests. The Hearing Coach software storing all results on a centrally hosted database.

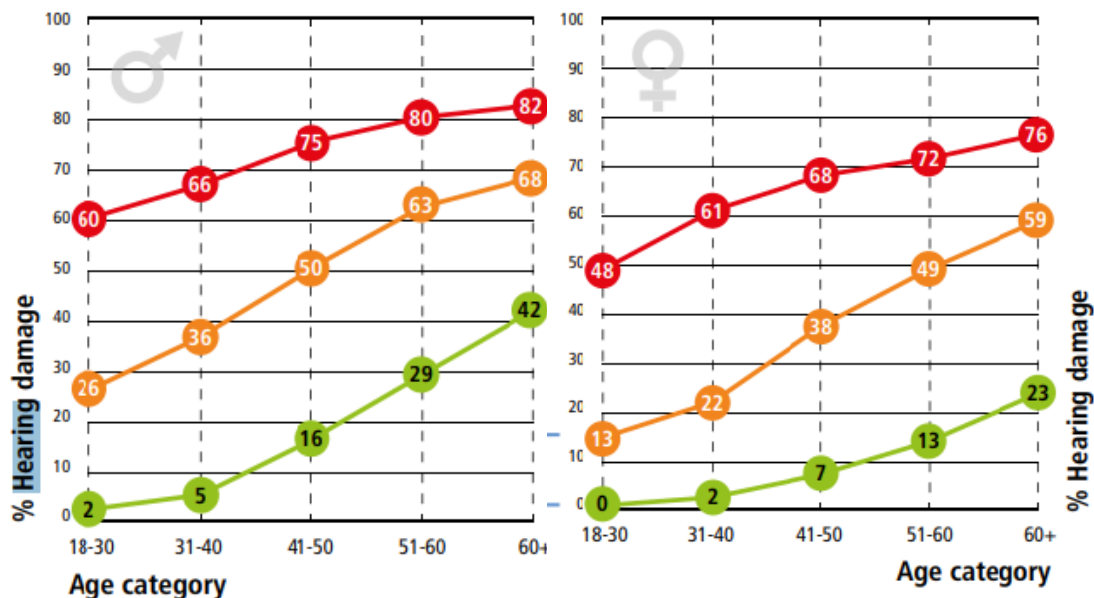


Figure 1 Overall Outer Haircell Damage by age and gender, 10, 50 and 90 percentiles

Analysis of figure 1 shows that for men at the 50% percentile the rule of thumb holds for all ages except one: 18-30 is 26, 31-40 is 36, 41-50 is 50, 51-60 is 63 and 60-60+ is 68. For women the 50% percentile value are all lower: 18-30 is 13, 31-40 is 22, 41-50 is 38, 51-60 is 49 and 60+ is 59. Combining the two sets of data, men and women, to explain to the patient their results provide the following percentages for the 50% percentile: 18-30 is 20,

31-40 is 29, 41-50 is 44, 51-60 is 55 and 60+ 64. This analysis provides confidence in the hypothesis with just one marginal case using an independently collected dataset.

## RESULTS

Otoacoustics emission assessments totaled, n=502. This compares to the 587 audiograms taken. This was mainly due to small amounts of ear wax blocking the ear probe making it impossible to accurately measure the emissions, a efficacy rate of 85.7%.

Table 1: Estimated Overall Outer Hair Cell Damage (%) for 18-30 Age Group

	General Population Male	General Population Female	Musician Left Ear Male	Musician Right Ear Male	Musician Left Ear Female	Musician Right Ear Female
10 Percentile	2	0	2	1	0	1
50 Percentile	26	13	15	13	8	9
90 Percentile	60	48	42	45	36	38

Comparing the percentiles for males, average age 22.27 stdev=3.17, and hence only considering 18-30 age range for the 10,50, and 90 percentages for Male musicians, n=249, there was a negligible difference between left and right ears in terms of OHC damage. When compared to the general population dataset at the 10th percentile level they were similar, see table 1, but at 50<sup>th</sup> percentile difference was 12% which increased to 16% at the 90th percentile. Hence, overall male classical music students had significantly better hearing than the general population. For reference the average result, n=249, for OHC damage was for the left ear 18.74 and the right 17.87%.

Comparing the percentiles for females, average age 21.86 stdev=3.04, and hence only considering 18-30 age range the 10,50, and 90 percentages for Female musicians, n=253, there was a negligible difference between left and right ears in terms of OHC damage. When compared to the general population dataset at the 10th percentile level they were similar, see table 1, but at 50th percentile the difference grew to 5 percentage points which increased to 6 percentage points at the 90th percentile. Hence, overall female classic music students had better hearing than the general population. For reference the average result, n=253, for OHC damage was for the left ear 14.52% and the right 15.84%.

Looking at the general population dataset, it can be seen that women consistently have lower OHC damage than men at all ages and this was replicated in the musician dataset for the 18-30 range. This supports the ISO 7029 audiometry derived dataset females having better hearing acuity than males [4]. As to the original hypothesis: OHC damage should be less than the age of the patient (as averaged for both ear) without considering the gender? The independently collected musician dataset, average age, 22.12 stdev 3.11, and the average OHC damage 16.7% provides a simple answer, it's good to be young(er).

## CONCLUSIONS

A new hearing assessment method has been tested for a specific group, that of students studying at a leading music conservatoire. These students were all young, 18-30 age range. Their hearing was assessed using pure tone audiometry and otoacoustic emissions. It was found that 86% of students could be tested using the Hearing Coach

software compared to every student using audiometry.

A hypothesis was formed in the summer of 2021 that the OAE damage should be less than your age to be considered to have 'Good' hearing. A dataset was produced by the developers of the Hearing Coach software which when analysed for all ages confirmed the hypothesis and this was further confirmed by an independently collect dataset of music students but only for the youngest age category.

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