Hearing in Musicians

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Dr. K. Rajalakshmi,

Professor of Audiology,

Department of Audiology,

AIISH,

Mysore.

Apoorva H.M.

Research officer

All India Institute of Speech and Hearing

Manasagangothri, Mysore-570006

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INTRODUCTION

Hearing is very crucial and enables us to work, socialize, interact, communicate and relax. Our hearing sense becomes important for the safety and to keep alert to the world around us. In this modern age of computers, telephones and mass media, one of the basic ways in which information is received is through our sense of hearing. Whether we are at work engaged in a meeting, listening to music or listening to our partner share their emotions and thoughts, accurate hearing becomes a most important aspect.

Hearing plays even more vital role in case of musicians. They rely on their hearing almost as they do on their voices/instruments. The dependency on good sense of hearing is both in terms of hearing very faintly presented tones and the ability to discriminate between different frequencies (Axelsson & Lindgren, 1981). The importance of having good hearing sensitivity has been under appreciated. Singers usually are very cautious about their vocal health care, but take less precautionary measures when it comes to hearing health care (Sataloff & Sataloff, 1993). For musicians, the sense of hearing can be considered as the most important 'instrument'. Consequently, this 'instrument' should be treated with utmost care, to protect the auditory sense in order to maintain musical perception and ability (Axelsson & Lindgren, 1981).

Professional jobs should not result in adverse effects on health is a generally accepted fact (Axelson & Lindgren, 1981). This concern is inconsistently raised across various professions. Effect of music on the auditory system has been studied extensively (Axelsson & Lindgren, 1981; Karlsson, Lundquist & Olaussen, 1983; Johnson, Sherman, Aldridge & Lorraine, 1986; Early & Horstman, 1996). It is reported that the music training has lead to better auditory processing abilities and speech perception abilities and thus musicians when compared to non-musicians exhibit enhanced (better) abilities in the auditory perceptual abilities (Musacchia, Sams, Skoe & Kraus, 2007; Parbery-Clark, Skoe, Lam & Kraus, 2009). This enhanced auditory perceptual abilities in musicians is a positive influence of music on the auditory system. On the other hand music may have its negative influence on the auditory system as the music performance typically requires a large number of musicians gather in a restricted area to present music which easily exceeds hearing damage and discomfort levels for shorter or longer periods of time. This is not only true for the performers but also for the listeners. It is generally recognized that intense pure tones and impulse noise may damage the hearing organ. Hence, the frequent occurrence of loud musical notes and impulse sounds in the musical environment suggests the possibility of developing hearing loss in classical musicians (Axelson & Lindgren, 1981).

Carnatic classical music which is listened to with pleasure is most frequently wanted sound (unlike noise), and cannot be compared to industrial noise (unwanted sound) which would cause permanent Noise Induced Hearing Loss (Chasin, 1998). However, since music is also characterized by its loudness, duration and quality, it may induce damage to the inner ear on long duration exposure resulting in hearing impairment to a minor or major extent depending on the individual susceptibility to noise (Burns, 1968). Hence, even classical music can be just as damaging as or more damaging than rock music or factory noise (Chasin, 1998). However, there are various factors influencing hearing in musicians – the frequency range of music exposed, intensity range of the music exposed, reverberation within rehearsal/practicing/teaching room, placement within an ensemble, genetic predisposition, duration of exposure and accumulated years of exposure (Axelson & Lindgren, 1981; Fearn, 1993).

Results of several studies (Emmerich, Rudel & Richter, 2008; Jansen, Helleman & Laat, 2009) indicate the prevalence of hearing loss in professional musicians to be 38–50%. Investigators (Behar, MacDonald, Lee, Cui, Kunov & Wong, 2004) have reported that 78% of the music teachers were exposed to sound levels exceeding 85 dB (A), when measured with a noise dosimeter. The loss of hearing also presents problems with loudness, frequency, and temporal perception and often includes ringing in the ears, or tinnitus. The hearing loss may be associated with diplacusis which may add on to the problems in musicians as it becomes difficult to tell whether they are playing/singing correct pitches. These losses and associated problems are critical to a musician who must correctly perceive and produce the accurate pitch, loudness, timbre, tempo, and style of a musical piece (Axelson & Lindgren, 1981). This severely affects their- professional and daily life and hence these conditions should be considered and treated as health care conditions.

There are however few contradictory studies (Karlsson, Lundquist & Olaussen, 1983; Johnson, Sherman, Aldridge & Lorraine, 1985) which report that music exposure is not oto-traumatic in nature. It is generally accepted that music tends to be more 'intermittant' and thus reduce the probability of causing hearing loss in musicians exposed to music when compared to the workers exposed to industrial noise (Chasin, 2008). Such differences caution against generalizing the results of industrial noise induced hearing loss to music induced hearing loss.

Hearing in musicians has been studied extensively in Western music and also on rock and pop musicians. There is a general misconception that only rock/pop music can cause hearing loss. Such studies on hearing abilities are least researched in classical musicians and those studied still report controversial findings as to whether music exposure is oto-traumatic in nature or not. Thus the present work is focused on studying hearing in Indian classical musicians specifically Carnatic classical musicians as Carnatic type is the most practiced and performed type of music in south India.

Also, though there are various studies (Jansson & Karlsson, 1983; Johnson, et.al., 1985; Philips & Mace in 2008) on sound level measurements of vocal output / various musical instruments, they have been studied when the individual is performing on stage (concert) or when the practice/rehearsal is going on. In the present study sound level measurement is done in a group situation where the artist/musician is involved in teaching his/her students. The musical sound exposed by a musician in teaching situation is most important aspect to be studied as most experienced artists are usually involved in teaching where they are exposed to music for long periods of time, sometimes almost every day. Moreover the teaching is carried out in group which may add to the loudness exposed by the teacher (musician). Hence, the sound level measurements of vocal output and instrumental output during teaching sessions is focused in the present study which represents more realistic situation of musicians being exposed to music in their daily routine.

Aim of the study:

To examine the hearing in vocal and instrumental classical musicians through audiological profiling and sound level measurements.

Objectives of the study:

1. To investigate the hearing status in vocal and instrumental classical musicians through questionnaire and detailed audiological profiling.

2. To determine the output levels of different musical instruments and vocal output in vocal musicians.

REVIEW OF LITERATURE

Hearing sense is considered to be one of the most important senses for musicians, as it provides crucial information during their musical practice and performance which require them to accurately match frequencies over a broad range in order to play proficiently. The effect of long term musical training on the auditory system has been studied extensively and is discussed below.

Positive influence of Music exposure/ training on the auditory system:

It has generally been accepted that musicians have better hearing acuity and musical perception for their age than non-musicians and/or amateur musicians (Schön, Magne & Besson 2004; Kazkayasi, Yetiser & Ozcelik., 2006). This may be mainly due to the musical training and practice which increases the spontaneous attention to the sound and their sound discrimination abilities.

Music being a complex auditory task fine tunes musicians auditory skills as they spend years together in intense music training (Gaser & Schlaug, 2003; Munte, Nager, Beiss, Schröder & Altenmüller 2003; Schlaug, 2001; Zatorre, Belin & Penhune, 2002). Findings have suggested that music training benefits auditory processing not only in the musical domain, but also in the processing of speech stimuli (Musacchia et al., 2007; Schon et al., 2004; Wong, Skoe, Russo, Dees & Kraus, 2007).

As evidenced by the various studies mentioned above, there exists structural and functional differences in the auditory processing abilities between musicians and non-musicians and thus music training influences temporal processing, speech perception in noise and auditory working memory.

Influence of Music Training/Exposure on Temporal Abilities:

Rammsayer and Altenmuller (2006) studied 36 academically trained musicians and 36 non-musicians. Seven different auditory temporal tasks were performed in the study. Auditory fusion, rhythm perception, and three temporal discrimination abilities were found to be superior for musicians when compared to non-musicians. The authors reported that temporal information processing is more accurate in musicians than in non-musicians.

Mohamdkhani, Nilforoushkhoshk, Mohammadi, Faghihzadeh and Sepehrenejhad (2010) conducted a study on 24 musicians and 24 normal hearing non-musician controls. GIN (Gap in Noise) test results (approximate threshold and percent of corrected answers) obtained was analyzed by a non-parametric statistical test. Results indicated that there was a significant difference between approximate threshold and percent of corrected answers between musicians and non-musician group. They concluded that musicians had rapid auditory temporal processing ability as compared to the non-musicians group as the musician group showed lower approximate threshold and the more corrected answers in GIN test. The authors attribute this to the effect of musical training on central auditory processing.

Thomas (2011) investigated temporal resolution abilities in musicians using psychoacoustic tests (GDT, TMTF). He reported that the temporal resolution ability becomes better as the years of musical experience of the musicians increased and the results were statistically significant.

Saha (2013) studied temporal resolution abilities in mridangam players by using tests – Temporal modulation Transfer Function (TMTF) and Gap Detection Test (GDT). It was found that temporal resolution abilities were better in mridangam players when compared to that of control group. It was reported that music training as a factor has contributed to better performance in musicians.

Influence of Music Training/ Exposure on speech perception in noise:

Hearing speech in noise is a difficult task for everyone and young children and older adults exhibit even more deleterious effects of background noise. Musicians, in contrast, demonstrate enhanced noise-exclusion abilities (Parbery-Clarket al., 2009). Musicians, as a consequence of training that requires consistent practice, online manipulation, and monitoring of their instrument, are experts in extracting relevant signals from the complex soundscape (e.g., the sound of their own instrument in an orchestra). A recent study found a distinct speech-in-noise advantage for musicians, as measured by standardized tests of hearing in noise (HINT, Hearing in- noise test; QuickSIN) (Parbery-Clark et al., 2009). Across all participants, the number of years of consistent practice with a musical instrument correlated strongly with performance on QuickSIN, auditory working memory and frequency discrimination. These correlations strongly suggest that such practice fine tunes cognitive and sensory abilities, leading to an overall advantage in speech perception in noise in musicians.

In order to find the effect of musical experience on the neural representation of speech in noise, Parbery-Clark et al. (2009) compared sub-cortical neurophysiological responses to speech in quiet and noise in a group of highly trained musicians and non-musician controls. Speech evoked auditory brainstem responses for speech syllable /da/ indicated that musicians exhibited more responses in background noise than control group. They also found that earlier response timing and more robust brainstem responses to speech in background noise were both correlated to better speech in noise perception as measured through HINT. They concluded that musical experience resulted in more robust subcortical representation of speech in the presence of background noise, which may contribute to musician's behavioral advantage for speech in noise perception. The authors speculated that extensive musical training may lead to greater neural coherence.

Thomas (2011) checked the ability to perceive speech in the presence of the noise in three SNRs (0 dB, -5 dB & -10 dB) and found that the speech perception in noise was better as the experience of the musicians increased. He concluded that as the experience of musician increased, the ability to perceive speech in the presence of background noise also increased, especially at lower SNRs.

Saha (2013) used Quick Speech Perception in Noise (Quick SIN) to assess speech perception abilities in the presence of background noise in mridangam players. It was found that Quick SIN scores were better in mridangam players when compared to that of control group.

Influence of Music Training/Exposure on Auditory Working Memory:

Many studies have shown that formally trained musician vary in their processing ability when compared to a non-musician group who have no exposure to music. It has been suggested that music training improves working memory. George and Coch (2007) examined 32 subjects: 16 musicians (8 female), 16 non-musicians (8 female). The electrophysiological test used was the P300 to measure the same parameters of memory. Results depicted better scores and better ERP latencies in the musicians, compared to the non-musician group.

Various studies (Brandler & Rammsayer, 2003; Chan, Ho & Cheung, 1998; Franklin, Moore, Yip, Jonides & Rattray, 2008) have demonstrated that musicians performed better in tasks involving verbal and auditory working memory. Some studies have reported that musical training have different effects on working memory abilities depending on the age at which the subject started his/her musical training. (Lee, Lu & Ko, 2007).

Negative influence of Music exposure/training on the auditory system:

The importance of hearing acuity for musicians cannot be overstated. Unfortunately, the levels of exposure during practice, rehearsal and performance are capable of damaging the hearing mechanism. Musicians are especially vulnerable to the effects of high noise levels due to their continual exposure in practice and performance (Early & Horstman, 1996). Though their exposure is intermittent, musicians still are at risk for suffering from the devastating effects of NIHL because of the sound levels produced by instruments.

Evidence has demonstrated that exposure to non-amplified and low intensity sound over a period of time has a positive impact on musicians, known as the 'protective mechanism of sound conditioning' against destructive effects of noise trauma (Niu & Canlon, 2002; Miyakita, Hellström, Frimansson & Axelsson, 1992). Such a protective mechanism of the auditory system may be limited, depending on the frequency range exposed, intensity and duration. In the study by Kazkayasi et al (2006), although their results indicated musical training had positive effects in terms of hearing acuity and musical perception using conventional audiometric measurements, they also found hearing reduction in extended high frequencies of 12, 14, and 16 kHz after two years of musical training and practice. The decrease in average hearing acuity at these frequencies might be attributed to continuous noise exposure.

There is ongoing debate regarding a correlation between high sound levels and hearing disorders. The most commonly assumed causes of hearing disorders that affect musicians are the high sound levels to which they are exposed (Hart, Geltman, Schupbach & Santucci, 1987;

Drake-Lee, 1992; Early & Hortsmann, 1996). These hearing disorders can manifest themselves in several ways, and can represent a great burden for those affected. From the previous studies done on classical musicians, five different hearing disorders were assumed to be caused by high sound levels resulting from music. They are: Hearing loss, tinnitus, hyperacusis, distortion, diplacusis (Kahari, Axelsson Hellstrom & Zachau, 2001). However, controversies are reported justifying the fact that music is more intermittent and varying having less detrimental effect on hearing acuity. Thus, few studies report that music is more pleasant and does not exhibit oto-traumatic effect on musicians. On the other hand there are various studies which report musicians are at risk to develop music induced hearing loss due to continual exposure to loud music.

Studies which report unaffected hearing with high levels of musical exposure:

Karlsson et al. 1983 studied 417 symphony orchestra musicians wherein the median values of age groups were compared with normative reference (Spoor & Passchier-Vermeer, 1969). It was found that there was no difference between the measured PTA in these musicians when compared with that of normative reference.

Johnson et al. in 1986 examined the hearing acuity among orchestral musicians compared to non-musicians. Using conventional audiometry (250-8K Hz) and EHF (9- 20K Hz) obtained thresholds were examined comparing musician versus non-musician, age and gender. It was found that the hearing acuity among the musicians and non-musicians were similar and a consistent decrease in hearing acuity as the frequency increased. The authors concluded that there was no prominent hearing threshold decline due to consistent noise exposure among musicians as well as no apparent gender or inter-aural differences.

Deatherage, 2003 studied the extended high frequency hearing of 66 subjects, aged 18-27 years. Subjects participated in the study included 33 musicians and 33 non-musicians. Comparisons between the extended high frequency thresholds (EHF) and conventional pure tone thresholds between musicians and non-musicians were made. The results revealed that there was no statistically significant difference in auditory thresholds between musician and non-musician group. The results however illustrated slightly better thresholds among the musicians than non-musicians in the EHF, though not statistically significant.

Studies which report affected hearing with high musical exposure:

Axelsson & Lindgren (1981) studied 139 classical musicians (122 males and 17 females) and found that 80 (58%) musicians were identified as having hearing loss and among them 51 (37%) had hearing loss being partially or wholly due to music exposure.

There was one more study in the year 1981 conducted by Westmore and Eversden wherein 34 orchestral musicians were considered in the study. 23 out of 68 ears (34%) showed audiogram pattern consistent with NIHL and 4 out of those 23 ears had a hearing loss more than 20 dB at 4 kHz.

Ostri et al. in 1989 studied 96 orchestral musicians (80 males and 16 females; aged between 22 and 64 years). In this study the PTA was compared to normative reference (ISO 7029) and it was found that 58% of musicians had hearing loss of which 50% of males & 13% of females showed typical audiograms of NIHL. Another finding of the study was significantly poor hearing thresholds on left ear were found at higher frequencies in violinists. Another study which compared the PTA with normative reference (ISO 7029) showed that the audiograms in 52.5% of ears suggested NIHL (Royster, Royster & Killion 1991). Royster at al. also reported significant poorer thresholds in the left ear when compared to right ear in violinists.

Mc.Bride, Gill, Proops, Harrington, Gardiner and Attwell (1992) examined 89 classical orchestral musicians by comparing the hearing levels between 18 woodwind and brass Musicians (high risk group) with 18 string musicians (low risk group) matched for age and sex. It was found that there was no significant difference in hearing thresholds between high risk group and low risk. The authors also confirmed that noise levels for classical musicians are not only considered uncomfortable but exceed permissible occupational noise level standards. Another study revealed that after exposure to unamplified music 31% of young musicians had a TTS of 15-20 dB. Approximately 50% of the subjects who had been exposed to amplified music had a TTS of 15-20 dB. Usually the TTS was measured at 6K Hz and the sources of the highest noise levels were percussion, brass and loud speakers (Fearn, 1993).

Kähäri et al. in 2001 compared 140 classical orchestral musicians (98 males and 42 females; aged between 23 and 64 years; mean age = 40 years) with normative reference (ISO 7029). The authors reported that the hearing thresholds for female musicians were significantly better than male musicians in high frequency and the median audiogram for male musicians displayed high frequency notch at 6 kHz.

Kähäri, Zachau, Eklof, Sandsjo and Moller in 2003 assessed hearing and hearing disorders among 139 rock/jazz musicians and found that around 74% of them had some or the other form of hearing disorders. Hearing loss, tinnitus and hyperacusis were most commonly seen hearing disorders. The 3-6 k Hz notch was shown and the woman showed bilateral significantly better hearing thresholds at 3-6 kHz than the men.

In 2006, Schmuziger, Patscheke and Probst studied 42 rock and roll musicians where PTA (0.25 to 14 kHz) was administered. Assessments of tinnitus and hypersensitivity to sounds were also carried out. The results of the study revealed significantly elevated hearing thresholds averaged at 3 to 8 kHz in musician group than the control group. 11 of the musicians (26%) were found to be hypersensitive to sound, and 7 (17%) presented with tinnitus.

Maia and Russo (2008) studied 23 rock and roll musicians. PTA, Tympanometry and OAE tests were used in the present study. The findings of the study showed that 100% of the ears presented thresholds within normal limits; however, 41% of the audiograms had notches at frequencies between 4 and 6 kHz. The results also revealed Reduced OAE amplitudes recorded in musicians (61% absent OAEs), even though hearing loss was not found. The authors also reported that the other hearing symptoms reported by the musicians were intolerance for intense sounds (48%), tinnitus (39%) and auricular fullness (22%).

Classical orchestra musicians (109) were studied by Emmerich et al. in 2008. PTA (0.25 to 16 kHz) and OAE tests were carried out in the study. The PTA criteria considered was the occurrence of permanent threshold shift (PTS) larger than 15 dB Noise levels which is generally reported to be higher than the regulated standards. The results of the study found that more than 50% of the musicians were found to have permanent hearing shift of 15 dB or more and there was a significant decline in OAE amplitudes which were correlated with the length of time of being professional musicians.

From the above findings it can be noted that music training/ exposure has both positive and negative influence on the auditory system. The above studies were related to audiological findings in musicians to investigate the effect of music training/exposure on the auditory system. There are also various studies related to sound level measurements of different musical instruments and vocal input which in turn reflect on probability of hearing damage risk in the musicians.

Studies on sound level measurements of vocal output and output of various musical instruments:

Folprechtov and Mikxovsk (1976) carried out sound level measurements of different musical instruments and measured sound levels of 92 dB (A) with variations of 87-98 dB (A) in a symphony orchestra. Usually the musicians performed 4-8 hours a day. The sound levels of the different instruments were as follows:

Instrument	Sound output
Violin	84 - 103 dB(A)
Cello	84 - 92 dB (A)
Base	75 - 83 dB (A)
Piccolo	95 - 112 dB (A)
Flute	111 dB (A)
French horn	90 - 106 dB (A)
Oboe	80 - 94 dB (A)
Trombone	85 - 114 dB (A)
Xylophone	90 - 92 dB (A)
Clarinet	92 -103 dB (A)

Jansson and Karlsson (1983) measured sound pressure levels during concert (symphony orchestra) and it was found that 'heavy' symphonic music exceeded the permitted dose for industrial noise equivalent to 85 dB (A). The authors concluded that if the risk criteria for hearing injuries caused by noise also apply to music, measures should be taken to reduce exposure to noise when 'heavy' music is played.

Royster et al., (1991) assessed the risk of NIHL among symphony orchestra musicians using sound level measurements. Personal dosimeter set to the 3 dB exchange rate was used to measure sound levels during rehearsals and concerts. The Leq values ranged from 79 – 99 dB (A), with a mean of 89.9 dB (A).

An assessment of noise exposure and hearing thresholds was carried out by Backus, Clark and Williamon (2007) in orchestral musicians during rehearsals and performance. The authors measured maximum personal daily noise exposure levels and it was found that the musicians were exposed to sound levels above 85 dB (A). The exposure levels depended strongly on the instrument being played and where the musicians were seated in the orchestra.

In a study by Philips and Mace in 2008, which was done with the primary objective of determining sound levels in student practice rooms, average sound levels and percentage of daily dose of noise exposure were measured. Also the authors determined whether any instrument group was at higher risk for music-induced hearing loss due to exposure levels. Brass, wind, string and voice instruments were measured in the study. Measurements were taken using a dosimeter or Dose Badge clipped to the shoulder during 40 students' individual practice sessions. Mean sound levels measured averaged 87-95 dB (A). Mean average levels for the brass players were significantly higher than other instrument groups.

Exposure to sound and the risk of noise-induced hearing loss in orchestral musicians was assessed by Wałbrzych in 2010. Sound level measurements were carried out within one opera and two symphony orchestras along with questionnaire inquiries in their employees. Based on this data, the risk of developing noise induced hearing loss was assessed according to ISO

1999:1990. The authors reported that the classical orchestral musicians are usually exposed to sound at equivalent continuous A-weighted sound pressure levels of 79−90 dB, for 20−45 hours per week. They also reported that exposures to such high sound levels over 40 years of employment might cause the risk of hearing impairment in the range of 4−30% and 16−43% in case of females and males, respectively. The authors measured the sound levels of different musical instruments and it was found that the highest risk is related to playing a clarinet (up to 35%), tube (up to 35%), trombone (up to 35%), trumpet (up to 40%), percussion section (up to 41%) and horn (up to 43%).

METHOD

Participants:

A total of 40 subjects were involved in the present study. All subjects participating in the study were between the ages 30-55 years. The participants were classified into 2 groups. The experimental group consisted of professional musicians who were involved in teaching music. Both vocal and instrumental musicians were considered. 5 vocal musicians and among instrumental music, 5 violinists (String), 5 Mridangam players (percussion) and 5 flutists (wind) participated. A total of 20 musicians participated in the study. 20 age matched individuals with non-musical background served as control group.

Subject Selection Criteria:

- All the participants were native Kannada speakers.
- Musicians were defined as those involved in practicing or performing music vocally or with an instrument (Violin/Mridangam/Flute) with musical proficiency of vidhwath.
- Also, all musicians were involved in teaching music.
- Average exposure to music should be a minimum of 12 years.
- Musicians should have no significant history of other noise exposure or ototoxicity
- Non-musicians were selected from a pool of volunteers who did not perform vocally or use a musical instrument for practice or performance and had fewer than two hours of exposure to loud music per week.
- There was no illness on the day of testing.

Testing environment:

All the testing was carried out in a sound-treated suite. The noise levels were maintained within permissible limits, as per ANSI S3.1- 1991.

Instrumentation:

A calibrated diagnostic audiometer Grason Stadler Incorporation, Model 61 (GSI-61) connected to TDH-50 P headphones encased in MX 41/AR ear cushions were used for conventional air conduction testing. A Radio ear B-71 bone vibrator was used for bone conduction testing. The same GSI-61 audiometer connected to HDA 200 Sennheiser headphones were used for high frequency audiometry. A calibrated Immittance Meter (GSI Tympstar) was used to assess the middle ear status. ILO 292 Echoport plus OAE analyzer was used for recording TEOAEs. A Digital Sound Level Meter (Equinox, EQ-805) was used for the measurement of the output levels of the instrumental music / vocal music exposed by the musicians while involved in teaching.

Procedure:

The testing was carried out in 2 phases.

Phase I: Audiological profiling of musicians and non-musicians

Phase II: Sound level measurements of professional musicians during teaching

Phase I: Audiological profiling of musicians and non-musicians:

All subjects underwent a questionnaire interview followed by Otoscopy, pure-tone audiometry, extended high frequency audiometry, speech audiometry, immittance audiometry and OAE measurements. To avoid effects of TTS all the evaluations were done after providing a hearing rest (> 8 hours without music exposure).

A **questionnaire** (Appendix I) was necessary to reveal case history information. Questionnaire was prepared which included 5 domains - Basic information, Musical history, Medical history, Life-style and Self-assessment of hearing status. The questionnaire was administered on both the groups (musicians and non-musicians). Information sought from musical history included queries on musical training and musical proficiency, regarding their musical performances/Concerts and on music teaching sessions and exposure to music during teaching hours.

Otoscopy was performed on all the participants wherin the ears were examined to check for the presence of ear wax, and to assess the eardrum status. Those with excessive cerumen and/or abnormalities of ear canal and/or eardrum were referred to otolaryngologist for medical management.

Pure-tone audiometric thresholds were measured using Grason Stadler Incorporation, Model 61 (GSI-61) audiometer. Air conduction thresholds were measured for frequencies from 0.25 kHz to 8 kHz. Bone conduction thresholds were obtained for frequencies from 0.25 to 4 kHz using a Radio Ear B71 bone vibrator. The audiometric thresholds were measured using the modified Hughson-Westlake method proposed by Carhart & Jerger (1959).

Extended high frequency audiometry was performed for 9, 10, 11.2, 12.5 and 14 and 16 KHz using GSI- 61 Audiometer. Hearing thresholds were determined according to Carhart and Jerger (1959) using a modified Hughson-Westlake procedure.

Speech audiometry was carried wherein speech recognition threshold (SRT) and speech identification scores (SIS) were obtained. Speech identification scores for both ears were obtained with Kannada monosyllables (Yathiraj & Vijayalakshmi, 2005). Monosyllables were presented to both ears separately at 40 dB SL with reference to SRT. A total of 25 words were presented to each ear separately. Each monosyllable was given a score of 4 %. Loudness Discomfort Levels was found wherein the minimum intensity at which tolerance problem for speech was noted.

Immittance audiometry included tympanometry and acoustic reflex measurements. Acoustic reflexes were obtained on all musicians at 500, 1, 2 and 4 kHz respectively.

TEOAEs were recorded using ILO 292 Echoport plus OAE analyzer by placing a probe with its tip positioned in the ear canal so as to give a flat stimulus spectrum across the frequency range. Stimuli were non-linear click trains of 260 sweeps with intensity of 85 dBpeSPL. The response was obtained using averaging method. The TEOAE amplitudes were recorded across frequencies.

Phase II: Sound level measurements during professional musicians involved in teaching:

A Digital SLM (Equinox, EQ-805) was used for the measurement of the output levels exposed by the musician when they were involved in teaching. The SLM had a condenser microphone with operating frequency 31.5 Hz to 8 kHz and intensity range of 35 to 130 dB SPL. The position of the microphone was placed at the ear level of the musician at 1 foot distance and at 45 degree azimuth. 60 – 100 SLM readings were taken over a period of 15-20 min (4 readings in a minute) and the Leq and Lmax were calculated.

Leq was calculated using the formula.

$$\mathbf{Leq = 10 \log [1/n \sum antilog (Li/10)]}$$

where, Li = instantaneous noise level for sample i

n = number of samples in the sampling time period.

This formula represents Leq of a number of discrete A weighted noise/music levels for a specified time period. For the ease of the calculation of Leq MATLAB software was used.

Lmax was calculated by converting the data into cumulative frequencies.

RESULTS AND DISCUSSION

The present study examined hearing abilities in vocal and instrumental classical musicians. The data obtained from 20 musicians and 20 non-musicians were analyzed using Statistical Package for Social Sciences (SPSS) software version 18. Descriptive statistics and non-parametric tests like Kruskal-Wallis and Mann-Whitney-U Test were used as the sub-groups in the musicians group had sample size less than 10.

The analyses were done to:

- Compare the auditory measures (pure-tone audiometric thresholds, extended high frequency audiometric thresholds, speech audiometry measures, Acoustic reflex threshold, and OAE amplitude) between experimental group and the control group.
- Compare the output levels of different musical instruments and vocal output in vocal musicians.

Phase I : Audiological profiling of musicians and non-musicians.

Questionnaire interview:

The number of years of music exposure ranged from 20 to 50 years. The number of hours of music exposure while teaching and performing ranged from 12 to 24 hours per week. None of the subjects had any history of ear discharge, ear pain or ear infections. Also, none of the subjects had a negative history in the domains - Life-style and Self-assessment of hearing status

Audiometric thresholds:

The mean audiometric thresholds obtained from the conventional audiometry (250 to 8000 Hz) and the extended high frequency audiometry (9000 to 14000 Hz) is given in table 1. It can be noted that in both the groups thresholds increased with increase in the frequency.

Also it can be seen that the mean auditory thresholds for violinists are found to be slightly higher in the left ear when compared to the right ear. However, the difference was not found to be statistically significant. Similar findings were obtained in previous studies (Ostri et al., 1989; Royster et al., 1991) wherein significantly poor hearing thresholds on left ear were found in violinists. This can be because of the asymmetrical noise exposure to the right and left ear due to the positioning of the instrument as it is placed closer to the left ear.

Table 1: *Mean thresholds for non-musician and musician group across frequencies.*

	Right (dB)					Left (dB)				
Freq (Hz)	Non Musicians (20)	Musicians				Non Musicians (20)	Musicians			
		Voc (5)	Mrid (5)	Flut (5)	Viol (5)		Voc (5)	Mrid (5)	Flut (5)	Viol (5)
250	7.75	9.00	9.00	6.00	7.00	6.45	8.00	6.00	7.00	12.00
500	11.75	9.00	9.00	8.00	8.00	10.00	6.00	8.00	12.00	13.00
1000	12.5	9.00	10.00	12.00	11.00	11.75	10.00	8.00	13.00	15.00
2000	14.25	12.00	9.00	13.00	12.00	10.25	9.00	7.00	14.00	14.00
4000	13.00	14.00	22.00	13.00	11.00	15.50	15.00	27.00	19.00	15.00
8000	18.25	21.00	18.00	20.00	14.00	23.50	18.00	15.00	21.00	22.00
9000	16.00	17.00	17.00	20.00	18.00	19.00	22.00	15.00	25.00	25.00
10000	22.25	24.00	18.00	27.00	26.00	19.75	25.00	19.00	27.00	24.00
11200	22.00	34.00	30.00	37.00	28.00	24.00	30.00	20.00	36.00	31.00
12500	29.75	40.00	36.00	32.00	28.00	30.50	41.00	32.00	45.00	32.00
14000	38.50	47.00	40.00	43.00	47.00	37.25	43.00	33.00	37.00	43.00

Each sub-group from the musician group was compared with the control group using Mann Whitney U test and it was found that there was no significant difference in auditory thresholds between each of the musician group and non-musician group (the z and p values are given in table 1).

Table 2: *Z and p values for auditory thresholds between musicians and non-musicians*

Freq (Hz)	**Right**		**Left**	
	Z	**P value**	**Z**	**P value**
250	-0.373	0.709	-0.530	0.596
500	-1.578	0.114	-0.248	0.804
1000	-1.603	0.109	-0.317	0.751
2000	-1.919	0.065	-0.738	0.461
4000	-0.996	0.319	-0.523	0.601
8000	-0.700	0.484	-1.052	0.293
9000	-2.030	0.062	-1.352	0.176
10000	-1.068	0.286	-2.259	0.064
11200	-1.437	0.151	-1.553	0.120
12500	-1.621	0.105	-0.939	0.348
14000	-0.511	0.609	-0.342	0.732

This finding is in coherence with the study carried out by Johnson et al. 1985 where audiometric thresholds (conventional – 250 to 8000 Hz and extended high frequency – 9000 to 20000 Hz) were compared between musicians and non-musicians. Also, Deatherage, 2003 had found a similar finding with extended high frequency hearing thresholds. Unlike various reports (Emeriti et al, 2007; Kothari et al, 2004; Jansen et al, 2008) which suggest music induced hearing loss, the finding of the present study conveys that classical music is not oto-traumatic in nature. However, 4k Hz dip was seen in Mridangam players, but the difference was not statistically significant.

Speech audiometry measures:

Speech Recognition Threshold (SRT), speech Identification Scores (SIS) and Loudness Discomfort Levels (LDLs) were studied and the mean values are tabulated in table 2. It can noticed that the mean values for SRT and SIS are similar across the musician group and non-musician group. However, LDLs were found to be higher for musician group when compared to that of non-musician group.

Table 3: *Mean speech audiometric measures for non-musician and musician group*

	Right (dB)					Left (dB)				
Speech measures	Non Musician (20)	Musician				Non Musician (20)	Musician			
		Voc (5)	Mrid (5)	Flut (5)	Viol (5)		Voc (5)	Mrid (5)	Flut (5)	Viol (5)
SRT (dB)	14.25	11.0	12.0	15.0	11.0	11.0	10.0	12.0	15.0	13.0
SIS (%)	98.8	99.2	99.2	99.2	100	99.2	100	99.2	98.4	100
LDL (dB)	100.5	103	106	105	104	101.25	104	107	104	105

To check if the difference in speech audiometry measures between musicians and non-musicians was statistically significant, each of the sub group from the musician group were compared with that of the non-musician group using Mann Whitney U test. It was found that there was no difference in SRT and SIS between the groups. However LDLs were found to be higher in musicians when compared to non-musicians and statistically significant difference was observed for flutist (Z = -2.23, $p < 0.05$ for right; Z = -1.41, $p < 0.05$ for left) and mridangists (Z = -2.49, $p < 0.05$ for right; Z = -2.70, $p < 0.05$ for left). A similar finding was found in a study done by Axelsson and Lindgren, 1981. They reported that musicians may be accustomed to wide dynamic ranges with daily exposures to sounds of varied intensities. Thus, higher LDLs observed for musician group can be attributed to the higher tolerance levels developed by them due to frequent exposure to musical sounds.

Acoustic Reflex Threshold:

The two groups did not show any significant difference for Acoustic Reflex Threshold at 500, 10000 and 2000 Hz when the data was analyzed using Mann Whitney U test. However the mean values (as given in table 3) show that musicians had higher ARTs when compared to the control group. Similar finding was also reported by Axelsson and Lindgren, 1981 where in the authors justify that the ART in musicians, often working in large dynamic ranges, ends to show elevated threshold values. They report that this may be an unconscious means of avoiding the distortion produced by the ART.

Table 4: *Mean Acoustic Reflex Threshold for non-musician and musician group*

	Right (dB)					Left (dB)				
Acoustic Reflex Threshold	Non Musician (20)	Musician				Non Musician (20)	Musician			
		Voc (5)	Mrid (5)	Flut (5)	Viol (5)		Voc (5)	Mrid (5)	Flut (5)	Viol (5)
500Hz	91.25	95.0	94.0	95.0	94.0	93.75	95.0	96.0	94.0	94.75
1000Hz	92.0	96.0	96.0	98.0	96.0	92.25	94.0	95.0	96.0	94.0
2000Hz	95.5	98.0	99.0	102	97.0	95.5	98.0	97.0	99.0	97.0

OAE amplitude:

The mean OAE amplitude values (SNR) for non-musicians and musicians are shown in table 4. Mann Whitney U test was carried out to compare each of the sub groups in the musician group with that of the control group. It was found that there was no statistically significant difference between musician group and the non-musician group. The finding of the present study is contradicting with the previous studies (Emmerich et al., 2008; Maia & Russo, 2008) wherein the OAE amplitudes were either reduced or absent when compared to the control group which also presented with hearing loss due to loud music exposure. In the present study though hearing thresholds were elevated at higher frequencies, this pattern of finding was found in both musician and non-musician group and there was no difference found between the two groups showing similar OAE amplitude between the groups. This finding again justifies that the hearing loss is not due to the music exposure, rather it can be due to the effect of aging as the study considers a wide age range of 30 – 60 years.

Table 5: *Mean OAE amplitude (SNR) for non-musician and musician group*

OAE amplitude (SNR)	Right (dB)					Left (dB)				
	Non Musician (20)	Musician				Non Musician (20)	Musician			
		Voc (5)	Mrid (5)	Flut (5)	Viol (5)		Voc (5)	Mrid (5)	Flut (5)	Viol (5)
	6.6	8.94	7.02	6.0	7.32	6.97	9.5	7.7	6.2	7.7

Phase II: Sound level measurements of professional musicians during teaching

The Leq and Lmax mean and standard deviation values are shown in the table 5. It can be noted that the flutists had the maximum sound exposure while teaching. Leq and Lmax values from highest to lowest is as follows - Flutists --- Mridangists --- Vocalists --- Violinists as can be seen from the figure 1. Thus, flutists are at the highest risk to develop hearing damage because of the loud music exposure. A similar finding was reported in a previous study by Folprechtov and Mikxovsk (1976) wherein the highest sound output was reported for flute - 111 dB (A).

Table 6: *Mean and standard deviation for Leq and Lmax for different musician sub- group*

Musician groups	Leq		Lmax	
	Mean dB(A)	S.D	Mean dB(A)	S.D
Vocalists	91.83	3.27	97.45	2.28
Mridangists	92.21	1.22	101.54	1.62
Flutists	101.54	1.62	107.3	2.61
Violinists	85.94	5.11	95.16	4.96

The Leq values across different musician sub groups were compared using Mann-Whitney U test. There was significant difference in Leq values between each of the sub-groups [Vocalists and flutists ($Z= -2.61$, $p< 0.05$); Vocalists and violinists ($Z= -1.15$, $p< 0.05$); Mridangists and flutists ($Z= -2.61$, $p< 0.05$); Mridangists and violinists ($Z= -2.19$, $p< 0.05$); Flutists and violinist ($Z= -2.61$, $p< 0.05$)] except between vocalists and mridangists where the difference was not found to be statistically significant. Since the sound levels measured are crossing the permitted dose for industrial noise equivalent to 85 dB (A), it is important to follow protective measures to preserve hearing sense in musicians.

In the present study, though the sound levels exposed by musicians are crossing the permissible noise limits, the hearing thresholds between musician and non-musician group were not statistically significant. This finding is in coherence with the study done by Johnson et al., 1986. The possible explanation could be the widespread music exposure and the desensitization of individuals to the high sound levels which would have made their ears tough for developing hearing loss (Deatherage, 2003).

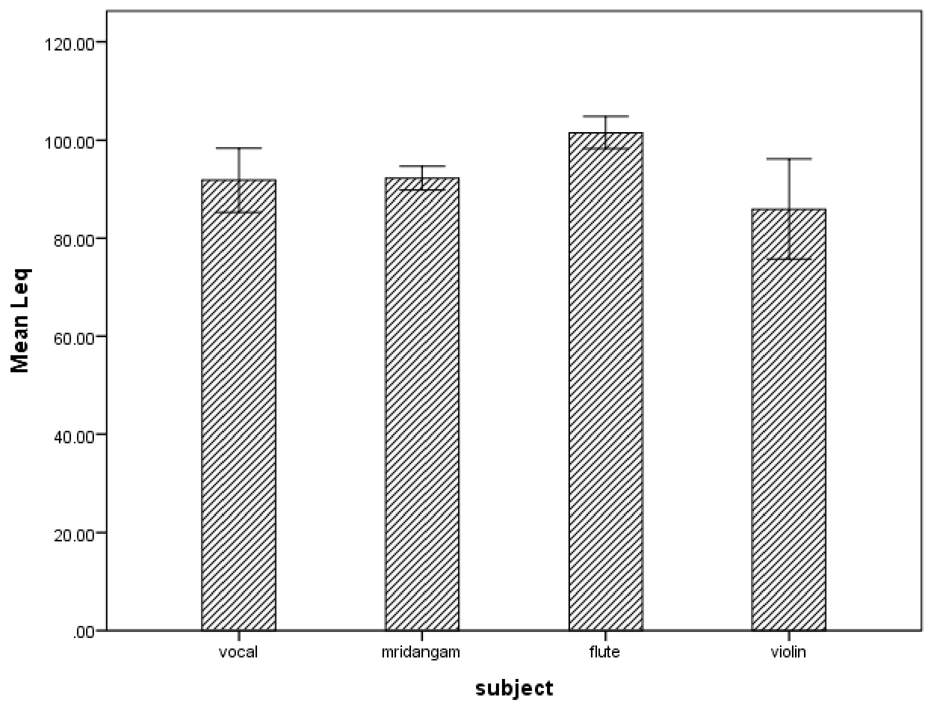

Figure 1: Mean Leq values [in dB(A)] for different musical instruments

SUMMARY AND CONCLUSION

Musicians are exposed to loud music more regularly and often than the general public during their practice and performance. Hence, it is reasonable to assume that professional musicians are most likely to have a high risk of music induced hearing loss. For classical musicians, various studies have showed around 83–112 dBA during practice and rehearsal time or on stage in symphony orchestras (e.g. Royster et al, 1991; McBride et al, 1992; Emmerich et al, 2008). Royster et al (1991) reported that the average musical noise equivalent exposure of classical musicians is like that of a standard working day (eight hours) at 85.5 dB A, which is slightly above the recommended safe threshold of 85dBA in industrial occupational settings (Canadian Centre for Occupational Health and Safety, 2008).

At exposure to such loud levels of music, hearing loss has been shown to occur in a higher proportion of professional musicians (e.g. Axelsson & Lindgren, 1977, 1981; Hart et al, 1987; Kähäri et al, 2003; Emmerich et al, 2008). The prevalence of music induced hearing loss in musicians varies between different studies depending upon study design and how hearing loss is defined. Studies have reported that incidences of hearing loss among classical musicians range from 37% to 58% (Axelsson and Lindgren, 1981; Ostri et al, 1989; Westmore & Eversden 1981, Royster et al, 1991; Emmerich et al, 2008). However there are few studies which report that exposure to music does not have any deleterious effects on hearing (Karlsson et al., 1983; Johnson et al., 1986 and Deatherage, 2003).

The present study aimed at examining the hearing in vocal and instrumental classical musicians and the study was carried out in 2 phases: Phase I: Audiological profiling of musicians and non-musicians. Phase II: Sound level measurements of professional musicians during teaching. 20 musicians and 20 non-musicians were considered in the present study. Musicians group consisted of 5 vocalists, 5 mridangists, 5 flutists and 5 violinists. Audiological profiling included questionnaire interview, Otoscopy, pure-tone audiometry, extended high frequency audiometry, speech audiometry, immittance audiometry and OAE measurements. Sound level measurements were done using a Digital SLM (Equinox, EQ-805). SLM readings were recorded and the Leq and Lmax were calculated.

The data obtained from the study were analyzed using SPSS software version 18. The hearing thresholds were found to be similar between the musician group and the non-musician group. It was also noted that left ear thresholds in violinists were found to be poorer than the control group which could be because of the asymmetrical sound exposure more towards the left ear. Also, in mridangists, slight 4000 Hz dip was seen, but the finding was not statistically significant. Loudness discomfort levels were found to be higher for flutists and mridangists which can be attributed to the higher tolerance levels developed by them due to frequent exposure to musical sounds. Also acoustic reflex thresholds were found to be higher for musicians than non-musicians though the difference was not found to be statistically significant. SRT, SIS and OAE amplitude were found to be similar between the musician group and the control group. Sound level measurements showed that the flutists had the maximum sound exposure while teaching. Leq and Lmax values from highest to lowest are as follows - Flutists --- Mridangists --- Vocalists --- Violinists. Thus, flutists may have higher probability of developing hearing problems as the sound level crosses 100 dB (A).

Musicians rely on their hearing for their livelihood and hearing difficulties has the potential to end their career (Chasin, 2009). Hence, hearing is crucial for musicians to continue performing at a standard, which is expected, and accustomed. Therefore monitoring the effects of noise on musicians' hearing is imperative (Deatherage, 2003).

Future directions:

- To investigate the correlation between the output levels of the instrument and the hearing thresholds with larger sample size.
- To consider a narrow age range (eg. 18 – 30 years) to avoid aging effect and also the negative impact on high frequency hearing sensitivity (Harrell, 2001). In addition, musicians should be matched as closely as possible for instrument and history of noise exposure.
- Longitudinal studies can be done to investigate the relationship between music exposure and NIHL in order to clarify possible risks and important factors.
- If in a particular group of classical musicians' music induced hearing loss develops, to trace and record the chronological changes in their hearing.
- To plan and institute appropriate hearing care measures for the musicians. Musicians should be counseled to consistently wear hearing protection (custom made musicians earplugs) and have regular hearing tests in order to prevent them suffering from hearing difficulties due to loud music exposure.

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Questionnaire for Musicians

I. Basic information

Name:	Age/Sex:	Date:
Education:	Occupation:	DOB:
Mother tongue:	Contact no:	

II. Musical history

- *Musical training and proficiency:*
  - Are you trained in any form of formal musical training? Yes/No

    If yes, which form of musical training? Vocal/Instrumental

    If instrumental, which instrument?
  - Onset (age) of musical training:
  - Since how long (no. of years) have you been practicing music?
  - How often do you practice music? (no. of hours / week) :
  - Musical proficiency:
  - Do you have any professional qualifications in music? Yes/No

    If yes, please describe:
- *Musical performances/Concerts:*
  - Do you give performances/concerts? Yes/No
  - If yes, how often do you perform?

    Once in a week/ once in 15 days/ once in a month/ once in 3 months/ once in 6 months/ once in a year
  - Usual performance/concert duration:

- Do you give performances in solo or with accompanists?
- If along with accompanists, who are your usual accompaniments?

- *Musicians who are involved in teaching:*
  - Do you teach music? Yes/No
  - If yes, which form of music? Vocal/ Instrumental
  - If instrumental, which instrument?
  - Total number of students you teach?
  - Do you teach in groups or one-to-one?

    If in groups, do you teach students in different batches? Yes/No

    If yes, how many students in a batch?
  - No. of hours spent on teaching in a day?

    No. of days spent on teaching in a week?

    Total hours spent on teaching in a week?

III. Medical history

- *Hearing health:*
  - Do you have hearing loss/ difficulty? Yes/No

    Ears: Right/Left/Both

    If yes, age of onset of hearing loss/difficulty:

    Nature of hearing difficulty: Progressive/ Fluctuating

    Specify difficult to listen situations if any:

    If you know, please specify what caused your hearing loss:
  - H/o ear discharge/ ear pain/ ear infections: Yes/No

    If yes, details of the same:

- ➢ H/o ear surgery: Yes/No

  If yes, details of the same:

- ➢ Do you have buzzing or ringing sensation (tinnitus) in either ear? Yes/No

  If yes, is it Constant or Intermittent?

  If constant, for how long will it last?

- ➢ Do you have any difficulty tolerating sounds (Hyperacusis)? Yes/No

  If yes, describe:

- ➢ H/o Dizziness/ Vertigo: Yes/No

  If yes, describe:

- ➢ Does anyone have history of hearing loss in your family?

- ➢ Have you undergone any hearing evaluation in the past? If yes, please describe the results and recommendation:

- *General health:*

  - ➢ Do you have Diabetes or H/o any other systemic diseases (like mumps, measles)? Yes/No

    If yes, describe regarding the same:

  - ➢ Any other medical problems/illness:

IV. Life-style:

- Do you smoke/ chew paan? – Yes/No

  If yes, how often?

- Do you consume large amounts of aspirin/ caffeine? Yes/No

  If yes, how often?

- Do you consume alcohol? – Yes/No

If yes, how often?

- Do you indulge in any other music exposure (ex: walkman usage, loud car stereo etc)? – Yes/No

  If yes, specify
- Do (Did) you work in a noisy environment? - Yes/No
- If indulged in noisy jobs, since how many years have you been working there?
- Do (did) you wear any ear protective devices (ear muffs/ ear plugs)?
- Were you exposed to any impulse noise (cracker burst etc.)?
- Do you indulge in any other noisy leisure time activities (listening to personal music system)? If yes, specify.
- When you were last exposed to noise/music?
- Do you take special care about your voice and vocal hygiene?

V. Self-assessment of hearing status.

- Do you hear people speaking, but have difficulty understanding the words?
- Do you notice you are favoring one ear over the other?
- Do you find yourself asking others to repeat themselves?
- Do people seem to mumble more often, making it hard for you to understand them?
- Do you have problems clearly understanding certain women's or children's voices?
- Do you have difficulty following conversations in noisy background?
- At what volume do you hear music or TV programs? Low/ Moderate/ High/ Very High.
- Do you have any problem in understanding or conversing over telephone?
- If you attend other musical programs, where do you prefer to sit?

Do you have any other concerns to share?

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