Effects of Discotheque Music on Audiometric Results and Central Acoustic Evoked Neuromagnetic Responses

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Abstract: Audiograms and auditory evoked magnetic fields (AEFs) were observed in young male and female adults at different ages before and after being exposed to discotheque music for 4 hours. Sound pressure levels (SPLs) ranged from 95 dB (SPL) up to 130 dB (SPL). After exposure, subjects had temporary threshold shifts up to 20–25 dB, which almost disappeared after 2 hours. The majority of the subjects suffered from tinnitus that lasted approximately as long as the temporary threshold shift. Correspondingly, a transient delay and prolongation of the main component of the acoustically evoked magnetic field (AEF) negative wave, occurring 100 msec after stimulus (N100m), was seen after this exposure; other components of the AEF (positive wave, occurring 50, 160, and 200 msec after stimulus [P50m, P160m, and P200m, respectively]) occurred less often as compared to nonexposed controls. Because effects of vigilance on the AEF could be excluded, these changes can be related to the loud music, indicating an influence of noise on central auditory processing. The transient tinnitus could be caused by acoustic microinjuries (hidden acoustic predamage) of outer hair cells, leading to the persistent hearing threshold shifts from which many young adults aged 20–24 years are suffering. Occurrence of tinnitus closely coincides with the changes in hearing threshold and AEF; thus, a limitation of loudness in discotheques is needed to prevent this kind of hearing hazard.

Key Words: audiogram; auditory evoked magnetic fields; discotheque; hearing loss; human

There is no doubt that noise-induced hearing impairment (e.g., so-called socioacusis) is caused by music listening habits in adolescents and in young adults [1–3]. In 1971, Luz and Hodge [4] investigated the mechanisms of temporary threshold shifts (TTSs) after noise exposure and of TTS recovery. They showed different modes of recovery that depended on the type of noise to which animals were exposed. Impulse noise resulted in delayed development of TTS and in slower TTS recovery than was experienced with continuous noise.

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Vibrations caused by low frequencies (percussion, drums, or electronic effects) are an important part of modern discotheque music. The feeling of modern music ("techno") is determined by the impact of those frequencies. Hamernik et al. [5] could demonstrate that those vibrations influence TTS also. Music modulated with vibrations expressed a hearing hazard greater than that of nonmodulated music at the same intensity.

It is not clear yet whether a TTS consists also of disturbances in central hearing processing and whether hidden damages in that processing remain, even if a TTS normalizes completely. Human ethical principles forbid producing such a TTS in human experiments, but volunteers can be examined before and after visiting a discotheque. This allows for the investigation of a TTS that usually occurs during such a visit and for a search for cochlear and central components of that

TTS, for frequency specificity of hearing disturbances, and for the time course profile of TTS development and recovery.

From the beginning of the 1990s, acoustically evoked magnetic fields (AEFs) have been used in neurophysiological basic and clinical research (e.g., in the department of psychiatry) to describe and to localize sources of neuronal activity [6–8]. These studies, however, did not consider mainly audiological diseases that might influence the source localization of AEFs, although a large body of reports has shown the influence of physical stimulation parameters, such as test tone frequency, tone intensity, duration, and interstimulus intervals, on source localization [6, 9, 10–12].

The aim of our study was to establish the effects of assessed TTSs after discotheque music listening on otoacoustic emissions (OAEs), on audiograms, on tinnitus, and on the source localization of cortical AEFs.

METHODS

Evaluation of Audiograms and OAEs

In 34 normally hearing young adults (aged 18–24 years), hearing thresholds and OAEs were assessed before and after a 4-hour visit to a discotheque. All participants in this study were volunteers and gave their informal consent before the data acquisition was performed. Hearing thresholds were established with the extended high-frequency audiometer type MA 22 (Grahnert Präcitronic, Dresden, Germany). OAEs were recorded with the Madsen-Capella system (GN Otometrics A/S, Denmark). Hearing thresholds and OAE measurements were performed in a noise-shielded chamber.

Additionally, in 36 young persons aged 16–18 years, in 64 young adults aged 19–24 years, and in 28 adults aged 25–30 years, hearing habits were assessed. For this purpose, questionnaires were prepared assessing the frequencies of visiting a discotheque, durations of those visits, habits of music listening in leisure time, use of personal listening devices and earphones, and occurrence of tinnitus.

Frequency spectra and intensity levels in the discotheque (Fig. 1) were recorded with a real-time frequency analyzer (Hewlett-Packard HP 3569A, Everett, WA) over a period of 4 hours. The frequency analyzer was placed in the audience, but similar data could be obtained at the place of the record operator (disk jockey). Higher sound pressure levels (SPLs) were found in the lower frequency range, between 0.4 and

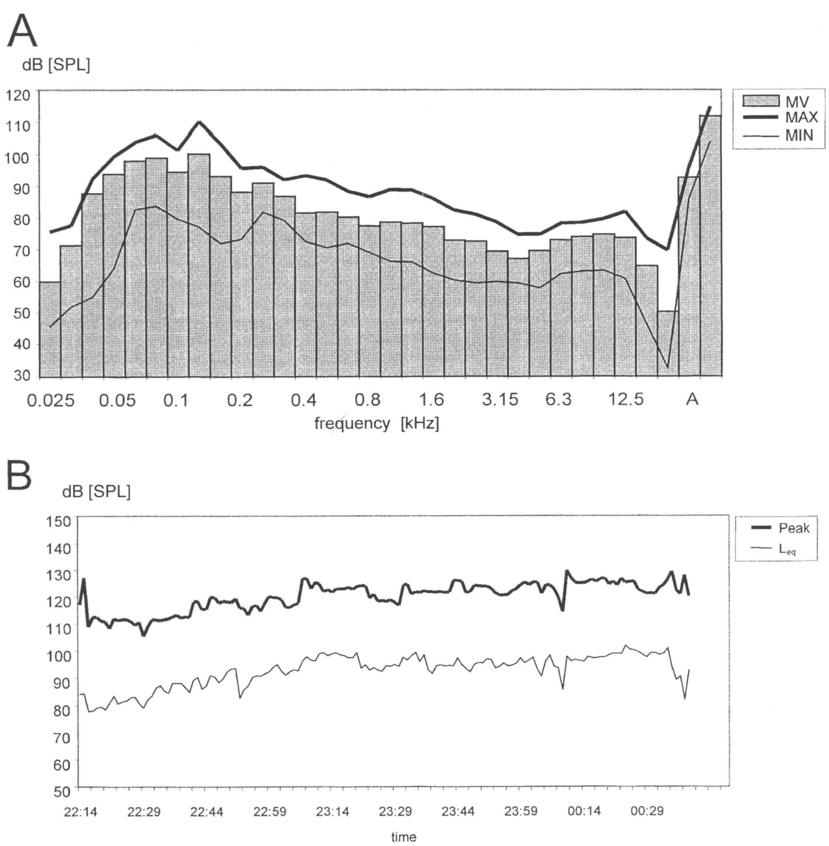

Figure 1. Results of sound measurements in the discotheque. The frequency analyzer was placed in the audience. (A) Frequency analysis obtained during "techno" music with a high level at deep frequencies. Gray bars show the mean sound pressure level (*SPL*) of each frequency analyzed; lines represent the minimal and maximal SPL values, respectively. (B) Continuous increase in loudness. A mean value of 95 dB(A) was established, but peaks of 110–120 dB(A) were found at the beginning of music exposure (22:14 P.M.) that rose to 125–130 dB(A) at the end of the discotheque visit (0:34 A.M.). Thick line gives the actual noise peak levels; thin line (L_{eq}) shows the energy-equivalent level of continuous noise. *MV* = mean value.

2.0 kHz, whereas lower levels were recorded at higher frequencies. A mean SPL of 95 dB with peaks of 110–120 dB was established. During the 4-hour evaluation period, the peaks increased continuously up to 125 and 130 dB SPL.

Recording of AEFs

In 18 young adults (mean age, 19 years), AEFs were examined immediately after the 4-hour discotheque visit and again 2 hours later. These data were compared with an AEF control recording before visiting the discotheque. To exclude disturbing influences of changed vigilance, those control AEF recordings were performed nightly also, but without a previous discotheque visit or exposure to other kinds of noise.

Test stimuli for AEFs were tone bursts (frequencies 0.5, 1, 2, 3, 4, and 5 kHz), with a duration of 50 msec, a rise time of 5 msec, and an intensity of 80 dB SPL. One series consisted of 128 single bursts with an interstimulus interval of 1,024 msec. To prevent electromagnetic disturbances, tone bursts were applied via an acoustically tested tube and funnel system to the contralateral ear of the subject.

AEFs were recorded with the Philips 2 × 31–channel double dewar device. The antenna consists of 31 first-order gradiometer coils in a liquid helium–cooled dewar. The coils were mounted spherically, allowing a better attachment of the complete sensor to the skull. The spherical sensor plate had a diameter of 140 mm. The cryostat was placed a minimal distance from the temporal skull of the subject without touching his or her hair. The subject was instructed to lie calmly with the head turned to one side and to keep the ear above the funnel system. With this localization of the sensor, AEFs were recorded over the temporal cortex, but parts of the parietal cortex, frontal cortex (down to the medial gyrus frontalis), occipital cortex including the gyrus angularis, and the cerebellum were also included in data acquisition. In each series, 128 trials of 512 msec each were recorded. Data were stored digitally on a personal computer and were evaluated off-line.

Data Analysis

Hearing thresholds and OAEs were evaluated before subjects visited the discotheque and were compared with the data immediately after the 4-hour visit, with data obtained 2 hours and 2 days after the visit without additional exposure to loud music or noise. AEFs were evaluated with the CURRY program, a commercial data analysis program (Neuroscan Labs, El Paso, TX) that was specially designed for evaluation of magnetoencephalographic data combined with nuclear magnetic resonance tomography [13]. For better recognition of the relevant signals, raw data were filtered digitally with a Fourier filter [14].

RESULTS

Hearing thresholds of the 36 subjects in this study (20 female, 16 male, aged 16–18 years) were almost normal. Men in this age group had a slightly lower hearing level than did women at the same age. These differences were statistically significant in the middle-frequency ranges (Fig. 2A). In subjects aged 19–24 years (n = 64; 41 female, 23 male) who were investigated in this study, however, a remarkable number of participants already had persistent hearing damage, especially at frequencies of 4–5 kHz.

Immediately after a discotheque visit, a TTS up to 20–25 dB SPL over all frequencies tested was found in all subjects. This TTS almost disappeared within 2 hours. Figure 2B depicts a representative example of such a TTS development and recovery in an 18-year-old woman.

Nearly 65% of the participants aged 16–18 years reported a tinnitus of a different kind after the discotheque visit. The same result was found when young adults between the ages of 20 and 24 years were questioned (Fig. 3). Differences were found between the gender groups also: Male participants aged 16–18 years reported the occurrence of tinnitus only rarely (<20%). In men aged 19–24 years, however, occurrence of tinnitus was reported in 60%, which resembled the occurrence in young women.

Exposure to loud discotheque music also affected AEFs. The typical noise effect on the main component of the AEFs, the N100m, is shown in Figure 4 (stimulus frequency, 1.0 kHz). On the night of a discotheque visit, the N100m is delayed and exhibits a longer duration than the N100m in control measurements by day. The latency shifts of the AEF components were transient and vanished 2 days after the discotheque visit. However, AEFs consist not only of the prominent N100m but of several additional components. When the various components of AEFs (i.e., N100m, P50m, P160m, and P200m) were compared, recordings on the night of discotheque visits and recordings by day showed different results. The N100m component was found consistently in 100% of the AEFs, regardless of whether measurements were obtained by day or at night after the discotheque visit. The P50m, P160m, and P200m components were noted during the day in 58%, 74%, and 68%, respectively, but at night after the discotheque visit in only 31%, 44%, and 61%, respectively.

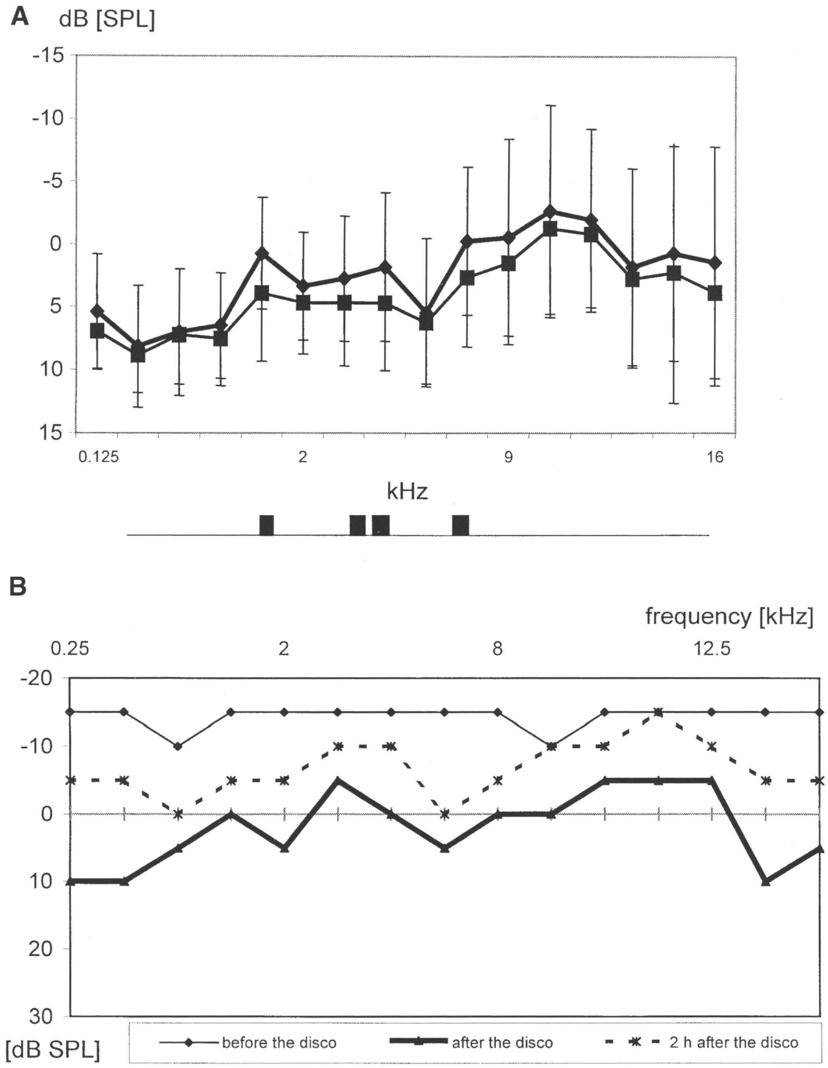

Figure 2. Hearing thresholds and hearing level shifts in young persons aged 16–18. (A) Mean values among 16- to 18-year-old male (thin line, boxed symbols) and female subjects (thick line, filled diamond symbols) (n = 36; 20 female, 16 male subjects). Black bars give statistically significant differences between the gender groups for the frequencies tested, respectively (Student's *t*-test, $p < .05$). (B) Representative example of a temporary threshold shift in an 18-year-old woman with normal hearing function (line with diamonds). Immediately after ending the discotheque visit, a hearing level shift up to 25 dB(A) was observed (line with triangles) that normalized only partially within 2 hours (line with crosses). *SPL* = sound pressure level.

Control measurements were performed to exclude influences caused by changed vigilance of the subjects investigated. The N100m of the AEFs taken at night without a previous exposure to disco noise showed nearly the same peak latency as the N100m of the AEFs obtained by day. We could show that there was only a small but negligible influence of tiredness on the peak latency of the N100m parameter. Therefore, we con-

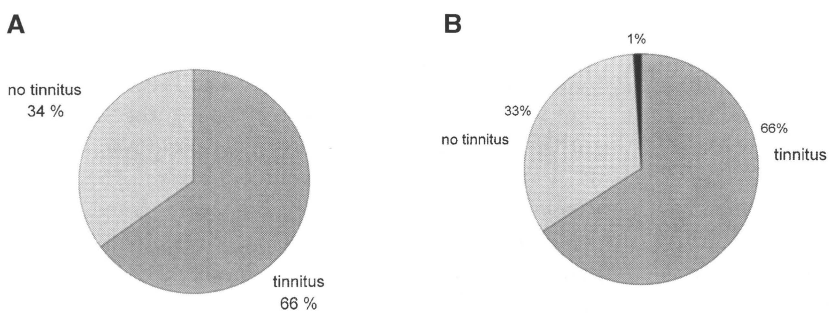

Figure 3. Comparison of occurrence of tinnitus after visiting a discotheque in (A) 16- to 18-year-old (n = 20) and (B) 19- to 24-year-old (n = 41) women. Approximately two-thirds of the female disco visitors suffered from tinnitus in both age groups. Only 1% of the 19- to 24-year-old group were unable to answer this question.

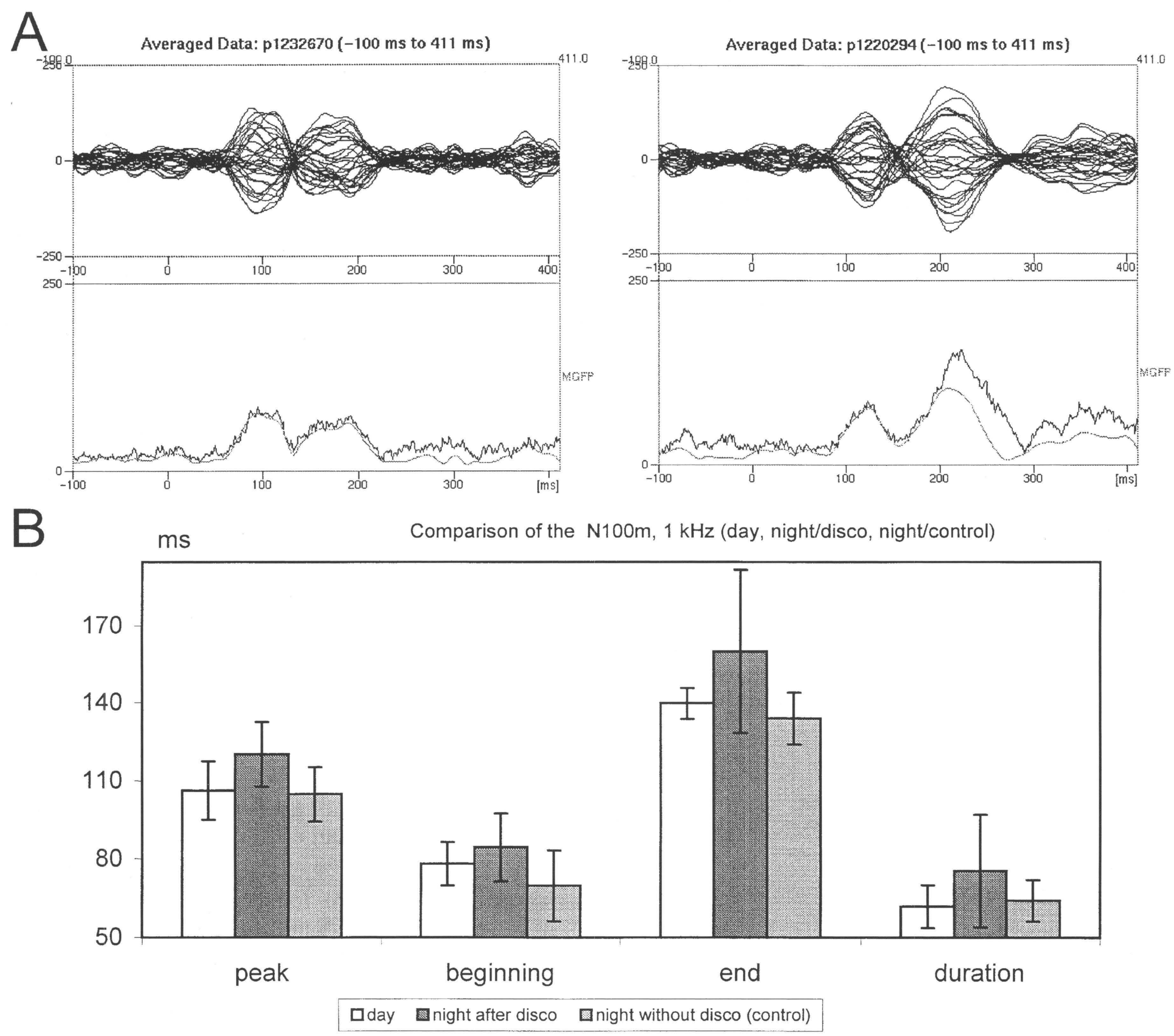

Figure 4. Representative example of discotheque noise effects on auditory evoked magnetic fields (AEFs). (A) Raw AEFs evoked by 1-kHz bursts, 70-dB sound pressure level (rise time, 5 msec; n = 128). Lower portion of diagram gives the mean global field power (nonfiltered and filtered) for this subset of AEFs. Control data are shown on left; on right, measurements are those obtained immediately after subjects' exposure to discotheque noise. (B) Mean values and standard deviations of time parameters of the N100m elicited by 1-kHz stimuli in five subjects (peak time, beginning and ending times, and duration). Comparisons are made among measurements by day, at night after 4 hours visiting a discotheque, and at night without previous discotheque music exposure. Note the clearly visible but insignificant increase in all parameters after disco music exposure. *MGFP* = mean global field power.

clude that the differences in peak time and in duration are caused by the noise of the discotheque and not by the vigilance of the subjects in the night.

DISCUSSION

The majority of discotheque visitors (both adolescents and young adults) suffered from tinnitus in the ear. These reports were in line with the audiometric data showing a TTS up to a 30-dB hearing level that usually disappeared within 2 hours after the music audience was ended. Similar observations were made by Delb et al. [15] and Lee [16]. In our study, 16- to 18-year-old male subjects reported tinnitus less often than did their female counterparts, but this difference vanished with aging. These gender-specific data could result from a growing interest in discotheque music in men older than 18 years.

The early occurrence of tinnitus accompanied by a TTS could be due to damage of cochlear outer hair cells. This assumption is supported by data from experiments on awake guinea pigs that were exposed to similar intensities of noise [17–19]. In these animals, scanning electron microscopy revealed early changes in outer hair cells. Although the tinnitus vanishes when a TTS recovers, a transitory tinnitus could indicate the beginning of a degenerative process in single outer hair cells [17–19]. The transient tinnitus that often is reported after noise or loud music exposure probably is caused by acoustic microinjuries that could be defined as hidden acoustic predamages [20]. An accumulation of those acoustic predamages is reflected in the increase in occurrence of a transitory tinnitus in young adults aged 20–24 years (both male and female). In this age group, an increasing number of persistent hearing threshold shifts (PTSs) were observed. Among the young adults aged 24 years and older, the number with permanent hearing damage rose to 25%.

Analysis of AEFs confirmed a frequency-independent increase of the N100m latencies after a discotheque visit that coincided with the duration of the TTS [7]. In contrast to the PTS, TTS did not cause shifts in source localization. The results of this study demonstrate differences between the incidence and duration of the components of the AEF. The differences clearly exhibit a temporary character that was confirmed by an investigation a few days after the disco visit. We suppose that there is a temporary change in the central auditory process caused by the SPL of the discotheque. Differences in localization of the sources of the N100m during daytime and nighttime and the influence of vigilance will be investigated [12, 21, 22].

Changes in AEFs are reversible during a TTS but not after a PTS. It is assumed that PTSs caused persistent reorganization in the auditory cortex. Latency shifts in the Heschl sulcus (area 41) of the cortex should reflect a different functional state of outer hair cells. Those latency shifts could be due to a changed transduction process in the inner ear but not due to reorganization after a PTS [23]. The delay could be a consequence of hearing information processing in subcortical stations of the auditory pathway [16, 24, 25].

Hearing damage caused by loud discotheque music is an important social problem [3, 26, 27]. The frequency of listening to discotheque music, use of earphones (with personal listening devices), and playing musical instruments explains in part the increasing number of hearing-impaired young adults [28–31].

SUMMARY

In summary, our study revealed the auditory hazard of discotheque music to young adults. All subjects who listened to disco music expressed a TTS after a 4-hour visit. With normal aging and increasing frequency of visits to a discotheque, the occurrence of tinnitus rose, which could reflect early microinjuries to outer hair cells that, in turn, form the basis for later hearing impairment. With regard to the early age at which young people begin to visit discotheques, schools should educate their pupils about the hazards of loud music.

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ERRATUM

In Volume 7, Number 2, 2001, of *The International Tinnitus Journal*, the names of several authors of "Falls in the Elderly: The Development of a Risk Questionnaire and Posturographic Findings" on p. 105 were misspelled. The authors of the article are Dario Alpini, Reuven Kohen-Raz, Riki Brown, Arie Burstin, Luigi Tesio, Luigi Pugnetti, Laura Mendozzi, Giuseppe Sambataro, Antonio Cesarani, and Davide Antonio Giuliano.