

Acoustic Sensitivity of the Sacculle and Daf Music

*Seyede Faranak Emami

Abstract

Introduction:

The daf is a large Persian frame drum used as a musical instrument in both popular and classical music which can induce a percussive sound at low frequencies (146–290 Hz) with peaks of up to 130 dB_{spl}. The percussive sounds have a power distribution in the region of saccular sensitivity. In view of the saccular stimulation by sound in humans, we decided to use cervical vestibular-evoked myogenic potentials (cVEMPs) to evaluate the possibility that the daf music may have a disturbing effect on saccular function.

Materials and Methods:

During this case-control study, 18 daf musicians were compared with 20 healthy individuals evaluated in the audiology department of the Hamadan University of Medical Sciences. Assessment consisted of pure tone audiometry, tympanometry, and cVEMPs.

Results:

Multiple comparisons of mean the cVEMPs and mean hearing loss at 250 Hz among the three groups (affected, unaffected, and normal ears) were significant. There were no significant differences between all daf players on high-tone loss at 3000 Hz. The daf musicians had bilateral unsymmetrical sensorineural hearing loss (SNHL), with hearing loss at 250 Hz (low-tone loss) and notched audiogram at 3000 Hz (high-tone loss). Eleven musicians with decreased vestibular excitability as detected by abnormal cVEMPs had mild (26–40 dBHL) low-tone loss and significant abnormal cVEMPs findings. In contrast, the others had slight (16–25 dBHL) low-tone loss with normal cVEMPs. Exposure to daf music is related to both saccular and cochlear dysfunction.

Conclusion:

Exposure to daf music is related to both saccular and cochlear dysfunction.

Keywords:

Hearing loss, Sacculle, Vestibular-evoked myogenic potentials.

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*Department of Audiology, faculty of Rehabilitation, Hamadan University of Medical Sciences. Hamadan, Iran.

Corresponding Author:

Tel: +989188118476, E-mail: faranak_imami@yahoo.com

Introduction

The vestibular system plays a primal role in the perception of musical rhythm (1). When we move to music we feel the beat, this feeling can shape the sound we hear (2), and we detect the melody in music. Visual information is not necessary for this effect, as it likely reflects a strong, early-developing interaction between auditory and vestibular information in the human nervous system (3). Vestibular input may play a key role in the effect of movement on auditory rhythm processing. Cortical and subcortical sites for the integration of auditory and vestibular inputs may underlie the interaction between movement and auditory metrical rhythm perception (2). The areas of the cortex can be activated by vestibular sensation to sound; namely, the frontal lobe (prefrontal cortex, premotor cortex, and frontal eye fields), parietal lobe (the region around the intraparietal sulcus, temporo-parietal junction, and paracentral lobule), and cingulate cortex (4).

Among the vestibular end-organs in mammals and humans, the saccular macula seems to respond particularly well to air-conducted sound (5,6). The frequency response of the saccule lies between about 50–800 Hz above about 90 dB_{SPL} (6). In the case of instrumental sounds, there is no doubt that many acoustic instruments possess sufficient power to exceed this threshold, particularly percussive instruments. Percussive music is also likely to have a power distribution in the region of saccular sensitivity (8). The intensities and frequency distributions that are typical in percussive music, such as rock concerts, dance clubs and celebrations, seem almost designed to stimulate the saccule (8).

In the history of Iran, the daf is a percussive instrument with important usage, particularly in celebrations. The daf (other names include *daire*, *dafli*, *dap*, *def*, *tef*, *defi*, *gaval*, and *duf*) is made with a metal screw system so that the head can be tightened and

tuned (Figure1). To date, no article has analyzed the daf intensity and frequency range and its effect on the vestibule. Thus, our aim is to use cVEMPs to evaluate the possibility that daf music may have a disturbing effect on saccular function.



Fig 1: A daf player

Materials and Methods

This case–control study involved 20 healthy subjects, consisting of hospital staff (10 females and 10 males). The case group were 18 musicians (5 females, 13 males) who had at least a 5-year history of working with the daf drum. The sampling strategy involved studying the harmful effect among all daf players in the Hamadian musicians group (Hamadan, Iran) with a history at least 5 years' exposure to the daf. The study was carried out in the audiology department of the Hamadan University of Medical Sciences between August and September 2013.

All the subjects received detailed information about the study and the assessments that would be involved. The exclusion criteria were history of ear infections, middle-ear diseases, and a family history of ear disorders which could interfere with cVEMPs measurements. The inclusion criteria were history at least 5 years' exposure to the harmful effect of the daf sound in the Hamadian musicians group.

Assessments:

After initial full auditory and vestibular examinations and recording of the medical history by our center otolaryngologist, full auditory and vestibular test batteries consisted of pure tone audiometry and tympanometry (Madsen, OB-822), impedance acoustimetry (Maico, MI. 34), and vestibular-evoked myogenic potentials (Labat Epic-plus). Every morning, calibration was checked to ensure that all instruments produced sounds at the specified level and frequency. We also ensured that all subjects completed the tasks properly throughout the study. All tests were performed on the same day. At each stage of the evaluation, when the procedure was completed for one test, subjects were given a short break while the whole procedure was repeated for another. We assessed daf signals via short-time-frequency analysis (time-frequency analysis identifies the time at which various signal frequencies are present, usually by calculating a spectrum at regular intervals of time), which was performed on a “segment-by-segment” basis and loaded into the Matlab workspace (Figure 2).

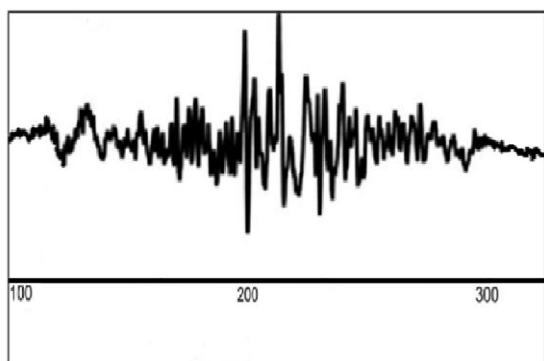


Fig 2: Time-frequency analysis identifies for a daf signal

Pure tone Audiometry:

Hearing thresholds in the normal range (-10 to 15 dB_{HL}) were obtained during the ascending/descending procedure from each subject over the frequency range 250–8000 Hz (9).

Tympanometry:

The middle-ear pressure between the limits of ± 50 dapa was recorded (10).

Cervical vestibular-evoked myogenic potentials (cVEMPs):

The active electrode was placed over the middle portion of the ipsilateral sternocleidomastoid muscle body. The reference and the ground electrodes were placed over the upper sternum and on the midline forehead, respectively. Auditory stimuli consisted of tone burst (500 Hz, 120 dB peak_{SPL}), rise/fall time = 1 ms, plateau = 2 ms, band pass-filtered; 20 Hz to 2 kHz, and a grand-average of the 200 responses was calculated using a standard evoked potential recorder (11).

The cVEMPs results for the control group were used as normative data and each wave was replicated. The cVEMPs asymmetry ratio was calculated according to the formula of Murofushi et al: $100 \cdot ((A_n - A_d) / (A_n + A_d))$, where A = amplitude of the cVEMPs, and R and L¹ refer to Stimulation of the right and left sides (11). Latencies longer than the calculated upper limit were interpreted as abnormal. Absence of a meaningful waveform with p13 and n23 was also considered to be an abnormal finding.

Data analyses:

All analysis was performed by means of the statistics software SPSS₁₇. Data were expressed as mean \pm standard deviation. The Kolmogorov-Smirnov test was used for evaluation of normal test distribution. One-way analysis of variance (ANOVA) was used to compare findings among the three groups. Tukey's least significant difference (Tukey HSD) test was chosen for *post hoc* testing. A P-value of <0.05 was considered to indicate statistical significance.

¹ There was no age effect for left-right difference in p13-n23 amplitude (11).

Results

Pure tone Audiometry:

All of the control group [mean (range) age 24 (20–39) years] had normal hearing. The case group¹ [mean (range) age 41 (32–46) years] had bilateral asymmetrical SNHL, with hearing loss at 250 Hz (low-tone loss) and notched audiogram at 3000 Hz (high-tone loss). The range of low-tone loss (250 Hz) in seven persons was 16–25 dB_{HL} (mean hearing impairment severity = 8 dB). The range of high-tone loss (3000 Hz) was 26–40 dB_{HL} (mean hearing impairment severity = 10 dB).

The range of low-tone loss in 11 subjects was 26–40 dB_{HL} (mean hearing impairment severity = 17 dB). The range of high-tone loss (3000 Hz) was 26–40 dB_{HL} (mean hearing impairment severity = 13 dB).

Cervical Vestibular-Evoked Myogenic Potentials (cVEMPs):

The main cVEMP evaluation in every subject in the case group was compared with those in the control group (Table 1). Abnormal cVEMPs were observed in 11 control subjects (22 affected ears), which showed an absence of both responses in one (n=2), and prolonged latencies with decreased peak-to-peak amplitudes in 10 subjects (n= 20).

Table 1: Mean p13-n23 latency values and peak-to-peak amplitudes of cervical vestibular-evoked myogenic potentials (cVEMPs) in normal ears and affected ears of the daf players.

Variable	Normal control ears (n = 40)	Affected ears (n = 22)
p13 (ms)	12.9 ± 1.4	17.3 ± 1.8
n23 (ms)	22.2 ± 1.6	29.4 ± 1.9
Peak-to-peak amplitude (µv)	67.9 ± 9.8	29.8 ± 18.6

¹Clinically abnormal VEMP for a patient over the age of 60 year may be entirely age related (7).

Main Outcome Measures:

Multiple comparisons of mean p13 latencies, mean n23 latencies, and mean peak-to-peak amplitudes of the cVEMPs among the three groups were significant (P=0.04 for all, one-way ANOVA test). Comparisons of mean p13 latencies in the affected ears vs the healthy ears were significant (P=0.03, Tukey HSD).

Comparisons of mean n23 latencies in the affected ears vs the unaffected ears and the control group were significant (P=0.02, Tukey HSD). Comparisons of mean peak-to-peak amplitudes in the affected ears vs the healthy ears were significant (P=0.01, Tukey HSD). The mean p13 and n23 latencies and the mean peak-to-peak amplitude in the unaffected ears (14 ears= 7 persons) were slightly longer than the respective means in the control group, but neither difference was significant (P=0.09). Multiple comparisons of mean notched audiogram at 250 Hz among the three groups were significant (P=0.00, ANOVA). Comparisons of the mean notched audiogram at 250 Hz in the affected ears versus the healthy ears were significant (P=0.01, Tukey HSD). There were no significant differences among all daf players on high-tone loss (P=0.95). Also, there were no significant differences in age or sex among three groups (P=1.24 for all, one-way ANOVA test).

Principal Results:

The daf musicians had bilateral asymmetrical SNHL, with hearing loss at 250 Hz (low-tone loss) and notched audiogram at 3000 Hz (high-tone loss). Eleven subjects with decreased vestibular excitability as detected by abnormal cVEMPs had *mild* (26 to 40 dB_{HL}) low-tone loss and significant abnormal cVEMPs findings. In contrast, seven musicians had *slight* (16 to 25 dB_{HL}) low-tone loss with usual vestibular sensitivity as detected by normal cVEMPs.

Discussion

In our study, all daf musicians had bilateral asymmetrical low-tone hearing losses at 250 Hz, which were comparable with the daf drum pitch. The daf can induce a percussive sound at low frequencies (146–290 Hz) up to 130 dB_{spl} peaks. A virtuoso daf player can decorate the rhythm of the songs in many exciting ways, and usually accompanies singers and players of the tambura, violin, oud, saz, and other Middle Eastern instruments. As the range of saccular sensitivity to sound lies at low frequencies, the daf drum can evoke a continuous response in the saccular nerve, and happens to coincide with the range of our voice pitch, which varies considerably among men (F0= ~100 Hz), women (F0= ~200 Hz), and children (F0 = up to 400 Hz). Also, the intensities in the vocal tract can be very high (up to 130 dB_{spl}) (12,13). Commonly, when the musician plays a daf drum, a large group of individuals vocalize and sing together. It is suggested that acoustically evoked sensations of self-motion may account for the compulsion toward loud music, and vestibular responses may be obtained from loud percussive music at intensities above 90 dB_{SPL} (14). The intensities of other instruments and the voice pitch of the singers add to one another and certainly stimulate saccular and cochlear afferents. Therefore, vestibular symptoms are triggered by acute exposure to their interaction effect and the possibility of low-tone hearing loss in daf musicians is confirmed.

It is important to note that the absence of both responses localizes the lesion to the end-organs, primary afferents, or nerve root entry zone (6). The peak-to-peak amplitudes represent the degree of response of the macular receptor of the sacculle whereas p13 and n23 latency represent the response of the nervous pathway, consisting of the inferior

vestibular nerve and the nuclei up to the sternocleidomastoid muscle (15). Applying this criterion to the data obtained, as well as the lower peak-to-peak amplitudes and the absence cVEMPs responses suggests that most daf musicians had peripheral pathology.

The impulse noise not only damages the cochlea, but also causes clear functional impairment to the vestibular end-organs, mainly the otolith organs (16), while noise affects hearing as well as the balance mechanism (17). The possibility of vestibular dysfunction, particularly the saccular pathway, is high in patients with noise-induced hearing loss (18). The greater the noise intensity, the more severe the damage on the cochlea and sacculle. The most severe effects of sound on human health can be observed on exposure to low-frequency-high-intensity sound, which is called vibroacoustic disease (VAD). This can result from the long-term presence of loud low-frequency noise (above 90 dB_{SPL}, below 500 Hz) in some occupational settings. Clinical manifestations of VAD involve irritability and depression, visual, auditory, and balance disturbances, epileptic seizures, and stroke-like neurological deficiencies, blood circulation changes, and arterial hypertension (19).

In this regard, the anatomical proximity of the sacculle to the stapedial footplate points to the possibility of acoustic trauma associated with saccular dysfunction (20,21). Under conditions of poor hearing, the sacculle has a facilitating role for the cochlea and can contribute to the detection of high-intensity low-frequency tones (22,23). The underlying mechanism may be simultaneous damage to both the cochlea and sacculle by the same factors. Absent or delayed cVEMPs in the ears after acute acoustic trauma may indicate poor prognosis with respect to hearing improvement (21). Therefore, abnormal

cVEMPs after acute acoustic trauma may be caused by saccular damage from very high-intensity noise (18). In contrast, normal cVEMPs is not a powerful indicator for potential for hearing improvement (20).

Conclusion

Overall, percussive daf musical sound seems to be related to both saccular and cochlear dysfunction. The associated degeneration in the cochlear and saccular afferents is associated with exposure to low-frequency-high-intensity percussive daf music; potentially reflecting their common sound sensitive function. Therefore, the cVEMP evaluation should be carried out in the battery approach tests of the auditory function for musicians. This can also be a sign of the changes that are taking place at low-frequency hearing thresholds.

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