

# Hearing threshold shift measured by pure tone audiometry after gun shot exposure in military personnel not using hearing protectors

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## Abstract

**Aims:** Awareness of the prevalence and intensity of acoustic traumas and the permanent impairments has an important role in planning preventive programs. This study was performed to evaluate temporary or permanent hearing threshold shift with the help of Pure Tone Audiometry among a group of military personnel in the shooting gallery.

**Methods:** In this cohort study performed in 2010, 40 military forces from a military unit in Tehran were selected by simple randomized sampling method. Pure Tone Audiometry was performed on samples before and immediately after gunshot exposure and also a week later. Threshold Shift (TS) analysis and comparison was done separately and for the mean frequency of 3 to 6KHz. Data were analyzed using descriptive statistical methods, Chi-square test and paired T-test by SPSS 17 software.

**Results:** After exposure to impulse noise, 28 individuals (70%) reported at least one hearing symptom that tinnitus was the most common one. Sixteen individuals (40%) showed TS increase in at least one of the studied frequencies. TS was only significant in the frequency of 4000Hz for the right ear ( $p=0.0001$ ) while separately evaluating the frequencies. The clinical findings and audiogram changes had remained in 8 and 6 participants respectively after one week.

**Conclusion:** Temporary or permanent threshold shift due to impulse noises can be detected by Pure Tone Audiometry. Assessment of hearing health in military personnel during the training courses and use of proper personal protective equipment is highly recommended.

**Keywords:** Hearing Threshold Shift, Gun Shot, Military Personnel, Pure Tone Audiometry

## Introduction

Acoustic trauma (AT) is one of the most important and preventable reasons of hearing loss in some jobs, especially in military jobs. Having contact with percussion or shocking sounds with sound pressure in a time period less than one second and the intensity higher than 100dB in scale of SPL (sound pressure level), through the mechanism of mechanical destruction of cochlear hair cells, causes temporary or permanent sensorineural hearing loss [1, 2]. Higher intensity sounds may cause eardrum rupture and dislocation of the bone [3, 4, 5].

Having contact with impulse noise is much harmful than continuous impulse noise [6], in the way that contact with permanent and percussion sounds with the intensity of 90 to 100dB, will result in the hearing loss of 30 to 50dB of hearing loss [7, 8]. On the other hand, the cumulative effect of impulse noise takes place in shorter time comparing with the continuous noise [9]. In terms of prognosis, AT may lead to permanent hearing loss, permanent damage to the eardrum or cholesteatoma. Also, the history of this complication is the most proved background incidence

of occupational hearing loss on subsequent exposures [10].

AT can cause the temporary threshold shift (TTS) and in some cases can cause the permanent shift (PTS) [11]. The incidence of permanent hearing loss is determined with hearing prolonged tests after exposure. This issue has been investigated in some foreign studies. However, it has not been studied in internal studies yet. On the other hand, according to some researchers, the accuracy and sensitivity of auto acoustic emission (OAE) is more than pure tone audiometry (PTA) in the diagnosis of AT [12, 13, 14, 15, 16, 17, 18].

The military forces, according to the mission assigned and mainly male individuals, due to the passing of the general conscription course, are in exposure to impulse noise (due to shots and explosions) and continuous sounds (aircraft engine, means of communication, military industry) [19] which respectively lead in AT and hearing loss due to noise (NIHL). The first two causes of disability in some military forces, are hearing loss and tinnitus [20]. Among the military forces who do not use ear protection in rifle ranges, the rate of hearing loss of

deaf is high [21]. So that in 45% of cases acoustic trauma happens for military people [10]. However, unlike the occupational hearing loss, there are no accurate and complete indexes for AT diagnosis [22, 23].

Considering the above issues and the fact that awareness of prevalence and severity of AT and also recognizing the predisposing factors play an important role in explaining the preventive programs, this study was conducted aiming at determining the rate of shift in temporary and permanent hearing threshold among a group of trained officers in rifle range using PTA.

## Methods

In this cohort study which was conducted in 2010, without control group, forty personnel of military services who were under training, who were in service for 6 months, in one of military unit located in Tehran were chosen by simple randomized method and were evaluated (80 ears). Sample size was determined based on the previous studies [3]. Inclusion criteria were: obligation to participate in the rifle range (training exercises) and shooting and consent to participate in the study. Exclusion criteria also included: any ear, nose and throat diseases, neurological diseases, history of chronic tinnitus, using ototoxic drugs, exposure to ototoxic chemicals, tympanic perforation, impaired initial audiometric, smoking and the history of exposure to continuous and impulse noises.

After receiving written consent, all the subjects of participating group were examined before contact in the specialized clinic by ear, nose and throat specialist for confirming the eligibility of participating in the study, and demonstrating demographic information. Then, participants were placed in the acoustic room and examined by audiologist using audiometer (Pejvac Ava model Head phone TDH 39, Bone vibrator B71, Iran) and underwent complete PTA through measuring bone and air conduction.

The shooting exercises included two rounds of shooting that in each round 10 bullets were fired. One round was in the form of single shootings and another one was in form of volley. Exposure to with impulse sounds in rifle range was measured and determined by the occupational hygienist using a Sound level meter (CEL-620A, England).

After exposure (3 hours later) participants again underwent a medical history, physical examination and PTA. Signs detected in examination were: fullness feeling in the ears, subjective hearing loss, tinnitus, vertigo, recruitment (discomfort when exposing to sounds) and difficulty in understanding conversation,

then TTS were calculated and hearing loss was defined at each frequency.

The subjects were assessed again one week after so that the level of their permanent damage be measured. The basis of the comparison was based on the changes in hearing thresholds separately in frequency of 4 and 6kHz in each ear and also the comparison of mean of hearing threshold in frequency of 2, 3 and 4kHz before and after exposure in each ear as standard threshold shift (STS). Also, this was conducted for the frequencies of 3, 4 and 6kHz [24]. For keeping morale principles in the study, the primary informing was done about the possibility of going out from the study in any time and being sure about the confidentiality of personal and medical information. Also, required predictions were conducted with respect to possible referral of cases requiring treatment.

After data collection, they were entered the SPSS 17 software and the descriptive information was analyzed by using the statistical methods of frequency and absolute statistical method, mean and standard deviation. For determining the normality of data distribution, K-S test was used. For determining the analytic statistics, paired T-test and Chi-square test were applied. In cases of quantitative variables with abnormal distribution, the nonparametric Wilcoxon test was used. The level of significance was considered to be less than 0.05.

## Results

The mean age of subjects was  $19.08 \pm 0.61$  years old, their minimum age was 18 years and the maximum was 23 years. Three subjects (7.5%) were left handed and none of the participants used the ear protection.

At the beginning of study, the mean of hearing threshold at different frequencies were all lower than 20dB and the difference between two ears in similar frequencies were not significant ( $p > 0.05$ , Table 1).

**Table 1-** The mean of auditory threshold in different frequency before exposure in subjects under study

Ear → Frequency ↓	Right		Left	
	Mean	Level of confidence 95%	Mean	Level of confidence 95%
250	2.25±5.76	0.14-4.09	4.12±5.41	2.39-5.86
500	6.75±5.25	5.07-8.43	5.75±5.37	4.03-7.47
1000	3.88±4.86	2.32-5.43	4.13±4.78	2.59-5.66
2000	7.00±4.77	5.47-8.53	6.63±4.58	5.16-8.09
3000	5.88±6.19	3.90-7.85	5.63±6.22	3.64-7.61
4000	7.38±5.99	5.46-9.29	7.00±6.07	5.06-8.94
6000	9.75±4.92	8.17-11.33	9.88±4.99	8.28-11.47
8000	7.50±3.92	6.25-8.75	7.38±4.08	6.07-8.68

The level of measured peak in each ear was measured from the frequency of 125 to 8000dB. The average duration of measurement was 12 minutes. The levels of pressure of impulse sound were varied between LIAM=72.9dB and LIAM=114.4dB.

Except for the eight frequencies (8000Hz of left ear and 2000Hz of right ear before exposure and 2000 and 8000Hz of left and right ear and 1000Hz of right ear immediately after exposure), the results of evaluation in all frequencies before and after exposure were normally distributed.

**Table 2-** The prevalence of signs and symptoms after exposure in participants in the study

Period→ Signs↓	Immediately after exposure		A week after exposure		Level of significance
	Number	Percent	Number	Percent	
The feeling of tight ear and hearing loss	8	20.00	3	7.50	0.001
Tinnitus	21	52.50	3	7.50	0.0001
Vertigo	13	32.50	0	0	0.0001
Recruitment	9	22.50	0	0	0.001
Difficulty in understanding conversation	10	25.00	2	5.00	0.0001
Ruptured eardrum	1	2.5	1	2.5	>0.05
People with at least one sign	28	70.00	8	20.00	0.002

Evaluation after exposure: After shooting training, 28 subjects (70.00%) had complaint of at least one hearing sign (Table 2). Accompanying of no one of signs with the hearing loss leading in significant STS was not obtained ( $p>0.05$ ).

Immediately after exercise, 16 patients (40%) had increase in hearing threshold at least in one of the frequencies out of whom in 4 people (25%), the damage was bilateral. Of the total damages, the threshold of 15 participants (93.75%) were mainly in the frequencies of 3 to 6kHz and one case of the increase of threshold in all frequencies was observed in right ear with the clear drop of hearing and the rupture of eardrum. Three participants of the total participants, had the STS loss in right ear (7.5%) that all of them had damage in one side and no case of STS was observed in left ear. In investigating the average threshold shift by three frequencies of 3, 4 and 6kHz, 7 participants had the threshold change of more than 10dB that 5 cases were in right ear and 2 cases were bilateral.

In the distinct analysis of frequencies, the differences in hearing thresholds before and after exposure was significant in the frequency of 4000Hz in right ear and ( $p=0.0001$ ) and it was nearly significant in the

frequencies of 3000Hz in both ear and in 4000Hz in left ear (Table 3).

**Table 3-** The average of hearing threshold in each ear in different frequencies before and after exposure

Stage→ Frequency↓	Before exposure		After exposure	
	Right ear	Left ear	Right ear	Left ear
2000	7.00±4.77	6.63±4.58	8.00±7.66	6.75±4.58
3000	5.88±6.19	5.63±6.22	7.38±6.88	6.37±6.60
4000	7.38±5.99	7.00±6.07	13.38±11.28	7.75±6.59
6000	9.75±4.92	9.88±4.99	11.38±7.76	10.13±4.93

The clinical complaints were remained in 8 subjects (28.57%) of people who had mentioned the hearing problems after exposure and the proportion of previous evaluation of appearing of all investigating signs and (except the rupture of eardrum) the number of people having symptoms had significantly decreased (Table 2).

Out of 15 cases of hearing loss without injury to the tympanic membrane, the hearing threshold of 9 cases (60.0% of disorders), were returned to initial state in all frequencies and it was remained in the same level immediately after exposure in 6 participants. These 6 cases included 2 cases of hearing loss in both ears and 4 cases of hearing loss in one ear out of which 5 cases (83.33%) showed the average loss of more than 10db in frequencies of 3 to 6kHz immediately after exposure (2 cases of both ears and 3 cases in right ear). No case of lacking threshold was observed one week after STS. In one case of eardrum rupture, the hearing threshold was continued to be similar to the immediate state of after exposure.

## Discussion

In the present study it was observed that even short-term exposure to impulse noise can lead to temporary or permanent threshold shift that can be detectable by PTA. In this way audiometric and clinically changes symptoms immediately after exposure were observed in 40% and 70% of subjects respectively exposed to 114.4dB. These figures were decreased by 15% and 28.75% a week after exposure. The most notable changes were observed in right ear and the frequency of 4000Hz and the changes in the mean frequencies of 3 to 6kHz was more stable than STS in evaluation of one week later.

In similar studies, encountering with sound pressure level of 127dB, 22% of participants had AT [25]. Also, in the studies on the military of England and US, the changes have been obtained to be respectively 20% and 20% to 30% [26, 27]. In the study in Thailand more than 64% of military personnel who

were active in the shooting training had sensory hearing-nervous loss [28]. However, since the indexes of diagnosis and division in AT is not complete compared to NIHL [22, 23], the comparison of different studies is not accurate.

Most findings show that in AT the frequency of 8kHz has remained intact and the frequency of 4kHz is more involved [29]. However, *Tombs et al.* in their research found that frequently the threshold drop occurs in the frequencies of 3 to 8kHz that the prevalence of changes in different points in this area does not have significant difference [30]. In the present study, also, no threshold change was observed in the point of 8kHz. Also, the drop of 4kHz was observed in 18 ears. On the other hand, in this study it was observed that investigating these frequencies shows the hearing drop in participants for investigating the changes of AT better and probably more sensitive than STS (in which the frequencies of 2, 3 and 4kHz are observed).

The results of some researches on the effect of impulse noises show that PTA does not have essential sensitivity for screening and the OAE test is more sensitive and objective in this domain [12, 18, 31]. What obtained in this study is to some extent different than this finding, in the way that in 40% of cases, the exposed participants showed changes in favor of acoustic trauma. Considering the low cost and availability, the choice of audiometer, compared to OAE, for screening is more justified. However, gun used in this study, produced the maximum acoustic pressure level of 110 dB that is considered a lower exposure limit compared to the high-caliber weapons [32]. Perhaps in more severe exposure, the ability of PTA screening is more than this. The prevalent signs of AT include tinnitus and feeling of fullness in the ears [20]. Among these, the most prevalent sign is tinnitus that is observed in 70% of cases [10]. This sign was observed in more than half of cases of exposure and near to 68.75% of cases of increasing threshold that is approximately close to these statistics. Tinnitus and the feeling of fullness is a prevalent phenomenon in the militaries that have regular exposure [33]. Also, in this study, the relationship of symptoms to STS and the changes of 3 to 6kHz were not significant. In encountering with impulse noises, some signs such as feeling of dizziness have central neural origin, rather than auditory origin [20] that can justify this issue to some extent.

Sometime stopping hearing loss for improvement of TTS needs several months [10]. Also, the progress of disorder, despite remove of exposure, is also seen even for a year. However, in most similar studies, monitoring of exposed subjects is not assessed after a

long period of exposure [3, 19]. According to the definition, permanent threshold shift (PTS) means the lack of hearing drop return during days or weeks of the lack of exposure. Perhaps, one of the features of this study was that evaluation was also done a week after exposure as well during which, no progress was observed about the shift of hearing threshold. It should be noted that there is no predictive factor for turning TTS to PTS [20]. In fact TTS is a sort of hearing tiredness that is a cause for PTS [1, 34].

Acoustic changes due to continuous noises happen in both ears in most cases and this is less true for acoustic trauma and what is more observed is unilateral conductive or nervous hearing loss [10]. Similar result was obtained in our study in the way that in 75% of cases AT was in one ear or unilateral and the hearing drop happened in left ear only in 4 cases that in all of them the hearing loss in right ear was also obvious. Since the intensity of receiving sound to ear has reversal relation to the second power of distance from the acoustic source and since all the subjects put the weapon on their right shoulder due to the dominance of the right hand (in this situation the received audio to left ear is less), this issue is justifiable. Another issue is this regard is that with the increasing the number of shots, we expect increase of difference and lack of symmetry in AT and increase in the difference of auditory drop in each frequency [35]. In AT, the bilateral threshold shift was seen in 25% of cases that this amount was 10% in the current study. On the other hand, 95% of damages in AT are sensory-neurological impairments that in our study was 93.75% [10].

The weapon used in this study produced relatively low sound compared with many other weapons. Encountering with this level of sound indicates the change of hearing threshold shift in remarkable number of people. However, militaries are exposed to impulse noises with higher intensity in their preliminary training and during their service. Thus, careful attention to hearing conservation program in military staff seems very essential. However, auditory protection against AT is very different from what is existed for NIHL. For instance, the role of engineering actions is less and the care for administrative control and personal protection is much more necessary [36]. Characteristics of exposure including the sound pressure level, duration of exposure, frequency of exposure and the type of sound (continuous, impulse, etc.) are effective on the intensity of hearing loss. Also, personal factors such as congenital sensitivity to voice [19], age [37, 38], cigarette smoking [39, 40, 41], non-occupational sound exposure [42, 43] and

disease or previous damage of ear [34, 35] have role in the amount of damages [42, 44]. Considering the exclusion criteria, the investigation of these factors was not available.

One of good characteristics of designing in this study was that evaluation was done before and after exposure. While, in many studies cross sectional sampling was used. Although according to forensic medicine, seven-day evaluation does not show the stability of hearing situation, it can somewhat stabilize the subjects from medicine and treatment program point of view.

Although in this study some cases of hearing drop was specified with PTA, evaluation with OEA is a more accurate and sensitive method. Another limitation of this study is non-existence of 6 and 12 months evaluation and not considering the control group. Another limitation that is observed in our study like many studies of military people is the phenomenon of "safe soldier". Therefore, generalizing the obtained information to non-military people should be done with percussion.

One of important result of this study was that hearing drop due to impulse noises happens in one ear and mostly in the ear in accordance to the dominant hand. Considering that the commanders consider the reduced communicative ability of forces due to using hearing protection in war field, maneuver and rifle range to be the cause of their avoidance to use this protective device, therefore, one ear or unilateral hearing protection can be suggested as a solution.

The results of this research, makes the necessity of attention to auditory health of military staff in training period more obvious. Therefore, clinical and paraclinical evaluation after exposing to impulse noises in appropriate intervals by using PTA, using appropriate personal protective devices, establishing of the occupational health clinics near the shooting fields (in order to diagnose and manage acute cases such as eardrum rupture, severe dizziness) and accurate choosing of people for subscribing in military units are suggested as relative priorities with respect to hearing health. With respect to personal protection it should be mentioned that using earmuffs is prioritized in the way that in a study, noise reducing more 22dB has happened only in 13% of subjects wearing earplug. Meanwhile using appropriate ear muffs has caused AT to be seen only in 1.5% of people that this finding has been reduced to 0.37% in reevaluation of three days later [46].

For the purpose of completing the findings of this study, researchers should investigate long-term follow-up of the population under study in 6 and 12

months intervals and also examine the role of personal protection in reducing the sounds.

## Conclusion

Temporary and permanent threshold hearing shift due to impulse noises is detectable with PTA. Also, concerning the hearing protection of militaries in training period, auditory screening and using suitable personal protective device seems to be essential.

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