The effect of hearing protection devices on speech intelligibility of Persian employees

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Research note

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Abstract

Objective: This study aimed to investigate the effect of hearing protection devices (HPDs) on speech intelligibility in Persian work environments. Three current earmuffs and three earplugs and one of the prototypes of molded earplug were tested on 15 male subjects which were randomly selected. The noise reduction of HPDs was measured based on the Real Ear Attenuation at Threshold (REAT) method. Speech intelligibility during using HPDs was determined based on the speech discrimination score (SDS) at two signal to noise (S/N) ratios (0 and +5). Data were analyzed using SPSS, version 22.

Results: The actual to nominal noise reduction rating values were from 47% to 84% for HPDs. The earmuffs showed higher ratios of actual to nominal noise reduction compared with the earplugs. At two S/N ratios, no significant differences were observed in speech intelligibility using HPDs ($p > 0.05$). However, at S/N ratio=0, the speech intelligibility descriptively has been improved by using common earmuffs up to 9.07 %. There was a significant difference up to 21.27% in speech intelligibility for proposed molded earplugs at S/N ratio=0($p < 0.05$). It is concluded that, if the trend of signal to noise ratio is positive, the HPDs will reduce the ability to understand speech.

Introduction

Given that conversation in the work environment is a means of communication, the presence of background noises or noises close to the frequencies of conversation, especially in office environments, can disrupt communication between employees and even interference with the conversation [1, 2]. The use of hearing protection devices (HPDs) can affect employees' speech intelligibility in noisy environments. Furthermore, the acoustic data of HPDs is one of the significant challenges for occupational health experts to assess the exposure levels of employees to noise. The amount of nominal noise reduction rating(NRR) of these devices, which is generally provided by the manufacturing companies in the identification card of these pieces of equipment, is mostly different compared to their actual noise reduction rating [3 , 4,5]. Among some methods disclosed for determining HPDs noise reduction, Berger et al. proposed the Real-Ear Attenuation at Threshold (REAT) hearing threshold method as the best and most accurate method based on the individuals' subjective responses [6, 7, 8].

Previous studies showed that the irregular use of HPDs in work environments can be due to difficulty in communication. For employees, communication with colleagues and also hearing signals from the equipment and devices is of great importance [9, 10, 11]. Nelisse et al. determined that only 64% of employees in that environment used HPDs, and only 20% used them consistently during full shifts. Some main reasons why employees did not use hearing protectors consistently were loss of their performance, lack of comfort, and interference in conversations with colleagues [12]. Hasahimito et al. revealed that a decrease in the noise reduction rates of hearing protectors cannot be considered as a factor for improving speech intelligibility [13]. Fernandes et al. showed that at the lowest background noise levels (60 and 70 dBA), HPDs reduced speech intelligibility while the background noise levels were approximately between

80 and 90 decibels and the signal to noise ratio (0, -5, and -10 decibels), HPDs improved speech intelligibility [14].

In developing countries, occupational health experts also reported that unreliable data of HPDs are considered the main challenge to achieve an efficient hearing conservation program [4]. The consequences of hearing protectors on verbal communication and speech intelligibility are of great importance in typical office work environments. Less attention has been paid about the speech intelligibility result from using HPDs in Persian office work environments. This study aimed to investigate the effect of hearing protection devices on speech intelligibility of Persian employees in the simulated office noise emission.

Methods

The subject population

In this experimental study, 15 male students of Hamadan University of Medical Sciences with an age range of 18-30 years were randomly selected. Pure tone audiometry was performed for selecting subjects with normal hearing. As shown in Fig. 1, three common commercial earmuffs and three earplug models (one foam formable and two 3-flange pre-molded) with technical specifications from reliable international manufacturers used in the Iranian's work environments were examined. A prototype of the proposed molded earplug designed based on subjects' ear shape and size was also tested. After careful examination of the ear canal and tympanic membrane of each participant by the study partner audiologist, the initial ear mold was made using soft material. Next, the molded earplug was made from it using silicone materials in the lab. A ceramic filter was placed inside the molded earplug so that it can produce a special channel to allow transmit normal conversation. The inclusion criteria for participating in the study included having normal hearing and vision along with Persian native language.

Experiment procedure

In each experiment session, based on REAT method, the hearing threshold of subjects was measured by a reference noise with and without a protective earphone for 40 minutes. Next, the speech discrimination score (SDS) of subjects with and without a protective earphone was measured at two signal to noise (S/N) ratios for 30 minutes. As mentioned, based on the REAT method, pure tone audiometery was performed to measure a person's hearing threshold with and without a protective earphone [15]. In this way, based on the insertion loss of HPDs in one-octave band frequency spectrum, the actual values of the noise reduction rating were calculated [16].

The values of sound attenuation used for calculation of the NRR were determined according to ANSI S3.19-1974 [17, 18]. In the next step, the ambient background noise was fixed at 70 dB, using speakers (Pejvak Ava CO). Two signal to noise ratios (0 and +5) were considered to relatively resemble noise emission in office work environment. The speech levels of the Persian world were adjusted based on

these S/N ratios. Participants sat in a chair two meters away from the noise emission speakers and avoided any movement during the measurement, as well as talking and making noise.

Speech intelligibility was measured based on the speech discrimination score and using a real two-channel audiometer (Piano model; Inventis CO). According to ISO 8253-3 standard, using a reliable and accurate list of one-syllable Persian words (25 words), the subjects are asked to repeat the words played from the speaker in the room environment. Then, the percentage of correctly repeated words is determined [19]. For speech audiometry, the speech of the Persian word from a suitable speaker with normal and clear speech with no particular accent was recorded. The speaker maintained the clarity, and natural speed of sound, and avoided emphasizing words during the record of speech [20].

Statistical analysis

Data were analyzed using SPSS software (ver.22, Chicago, IL, USA). The normality of the data was tested using the Kolmogorov-Smirnov test. When data were normally distributed, they were analyzed using paired sample and student T-tests. Wilcoxon's tests were also used when data were not normally distributed. The significant level for all tests was set at 5%.

Results

The results showed that the actual to nominal NRR ratio is about 47 to 84 %. In the current study, the real to nominal NRR for earplugs was in the range of 47 to 76%, and for earmuffs, it was in the range of 74 to 84% ($p < 0.05$). The studied earmuffs showed higher ratios of actual to nominal noise reduction compared with the earplugs. Actual NRR for a proposed prototype earplug was 12.5 dB which was comparable with the real data of the other studied traditional earplugs.

The subjects' speech ineligibility in no background noise, S/N = 0 and S/N = + 5 conditions were 98.00±1.20, 62.93±2.90 and 72.00+2.70 respectively. There was a significant difference between the subjects' speech ineligibility without earphones in these mentioned conditions ($p < 0.05$). A significant correlation is observed between the speech intelligibility in these two signal to noise conditions ($r = 0.79$ and $p < 0.05$). Table 1 showed the subjects' speech intelligibility with and without earphones at S/N = 0. The result showed that there was a significant difference in speech intelligibility for molded filtered earplugs ($p < 0.05$), however, no significant differences were observed in other HPDs ($p > 0.05$). However, the speech intelligibility descriptively has been improved by using some common earmuffs up to 9.07 %. The common earplugs have an intangible effect on speech intelligibility. However, the proposed molded earplugs could increase speech intelligibility by up to 21.27%.

Table 2 showed the subjects' speech intelligibility with and without earphones at S/N = +5. The results showed that there were no significant differences in speech intelligibility in all examined HPDs ($p > 0.05$). The results showed that HPDs have not notable effect on speech intelligibility at S/N = +5. The speech intelligibility descriptively has been improved by using common earmuffs by only 1.87 %. The common

earplugs improved speech intelligibility by only 2.13%. The molded filtered earplugs could increase speech intelligibility only up to 3.6%.

The results showed that there was a significant correlation between two signal to noise ratios($r = 0.79$ and $p < 0.05$). The results showed that there was a significant correlation between noise insertion loss and the percentage of speech intelligibility ($r = -0.37$ and $p < 0.05$). The results showed that there was a significant correlation between noise insertion loss and the percentage of speech intelligibility ($r = -0.224$ and $p < 0.05$).

Discussion

Occupational health experts seek to strike a balance between employee hearing protection and their ability to communicate. The current results proposed some local derating patterns for the labeled noise reduction of the common HPDs. The actual noise reduction for all studied HPDs is less than their nominal noise reduction, which is consistent with the findings reported by Biabani et al. and Norain et al. [21, 22]. The studied earmuffs showed higher actual acoustic performance compared with the earplugs. The noise protection data of the tested hearing protectors were relatively similar to the National Institute for Occupational Safety and Health (NIOSH) derating patterns. NIOSH proposed that subtraction of 25% from the manufacturers' labeled NRR for earmuffs, and 25 to 50% for earplugs [16]. Low quality of the existing models of earphones in the real market and the appropriateness of the size of the earplugs and earmuffs to the anthropometric dimensions of the employees are the main reasons for the difference in actual performance values with the manufacturer's nominal values. The flanged earplugs have a higher noise reduction compared with foam formable earplugs.

The participants correctly recognized 98% of the Persian words in silent conditions without HPDs. However, the percentage of identified correct Persian words were reduced to 72% and 62.93% at S/N =+5 and S/N= 0, respectively. Statistically, the observed trends were significant and indicate that the background noise level is very effective in the ability to understand speech. Some HPDs at S/N =0 had more effect on improving speech intelligibility compared with at S/N= +5. Ljung et al. showed that speech intelligibility was reduced linearly with an increase at the signal to noise by using protective earphones, which was consistent with the results of the present study [23].

Fernandez et al. showed at positive signal-to-noise levels, earphones reduced speech intelligibility and when the signal-to-noise levels were negative, earphones increase speech intelligibility. In industrial environments, where the signal-to-noise level is usually negative, HPDs can considerably improve employees' verbal communication in addition to preventing hearing loss. The use of HPDs has affected the ability to understand speech up to 3.6 % at S/N= 0, and about 3 % at S/N= +5, which showed the decreasing trend of speech intelligibility with the increased signal to noise which was relatively similar to the present study[14]. Dastpak et al. showed that using HPDs can improve speech intelligibility by increasing background noise from 75 decibels to 95 decibels which were somewhat consistent with the present study [24].

A proposed molded earplug can considerably improve the speech intelligibility compared with the studied traditional HPDs while maintaining acceptable noise reduction. It can be concluded that, for reducing the gap between HPDs' traditional hearing protection and speech communication, some new designs on HPDs intelligently may improve communication of employees while also maintain acceptable noise reduction. The results showed at S/N =+5, the percentage of speech intelligibility more decreased by increasing the insertion losses compared to the S/N =0. Therefore, in higher signal-to-noise ratio, HPDs with higher insertion loss can more reduce the speech intelligibility.

Conclusions

Speech communications in work environments are always challenging while wearing hearing protection. The actual noise reduction for the studied HPDs is less than their nominal noise reduction so that the studied earmuffs show higher actual acoustic performance compared with the earplugs. The HPDs at S/N =0 has a higher effect on improving speech intelligibility of the Persian words compared with at S/N= +5. It seems that, if the trend of signal to noise ratio was positive, the HPDs will reduce the ability to understand speech. It is verified that molded filtered earplugs considerably improve the speech intelligibility compared with the studied traditional HPDs while also maintain acceptable noise reduction.

Limitations

The interpretation of the current results is limited to two signal to noise ratios only simulated office noise emission. It is proposed that employees' speech intelligibly were examined while using common HPDs at the other signal to noise ratios such as -5, -10, etc.

Declarations

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Authors’ contributions

MK contributed to acquisition and analysis of data.

MA contributed to study conception and design, analysis and interpretation of data and drafting manuscript.

RG contributed to study conception and design.

MHN contributed to study conception and design and acquisition of data.

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Availability of data and materials

The datasets during and/or analyzed during the current study available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Hamadan University of Medical Sciences with IR.UMSHA.REC.1397.918. After being informed about this research, each subject completed consent form.

Consent to publish

Not applicable.

Competing interests

The authors state that they have no competing interests.

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Abbreviations

HPDs: hearing protection devices; REAT: Real Ear attenuation at Threshold; SDS: speech discrimination score; NRR: noise reduction rating; S/N: signal to noise; NIOSH: National Institute for Occupational Safety and Health

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Tables

Table 1 The subjects' speech intelligibility with and without HPDs at S/N = 0

HPDs types	With HPDs (%)	Without HPDs (%)	p value	Difference (%)
Earplug A1	63.20±1.30	62.93±2.90	0.71	0.27
Earplug A2	63.47±6.30	62.93±2.90	0.86	0.54
Earplug A3	63.98±4.80	62.93±2.90	0.88	1.05
Earmuff B1	64.00±3.70	62.93±2.90	0.64	1.07
Earmuff B2	72.00±2.40	62.93±2.90	0.58	9.07
Earmuff B3	72.00±3.40	62.93±2.90	0.13	9.07
Prototype earplug	84.20±3.50	62.93±2.90	**0.04**	21.27

Table 2 The subjects' speech intelligibility with and without HPDs at S/N = +5

HPDs types	With HPDs (%)	Without HPDs (%)	p value	Difference (%)
Earplug A1	74.13±4.40	72.00±2.70	0.15	2.13
Earplug A2	72.80±2.10	72.00±2.70	0.71	0.80
Earplug A3	72.10±1.10	72.00±2.70	0.70	0.10
Earmuff B1	73.87±5.60	72.00±2.70	0.10	1.87
Earmuff B2	72.00±5.20	72.00±2.70	0.41	0.00
Earmuff B3	72.00±2.20	72.00±2.70	0.90	0.00
Prototype earplug	75.60±3.60	72.00±2.70	0.10	3.60

Figures

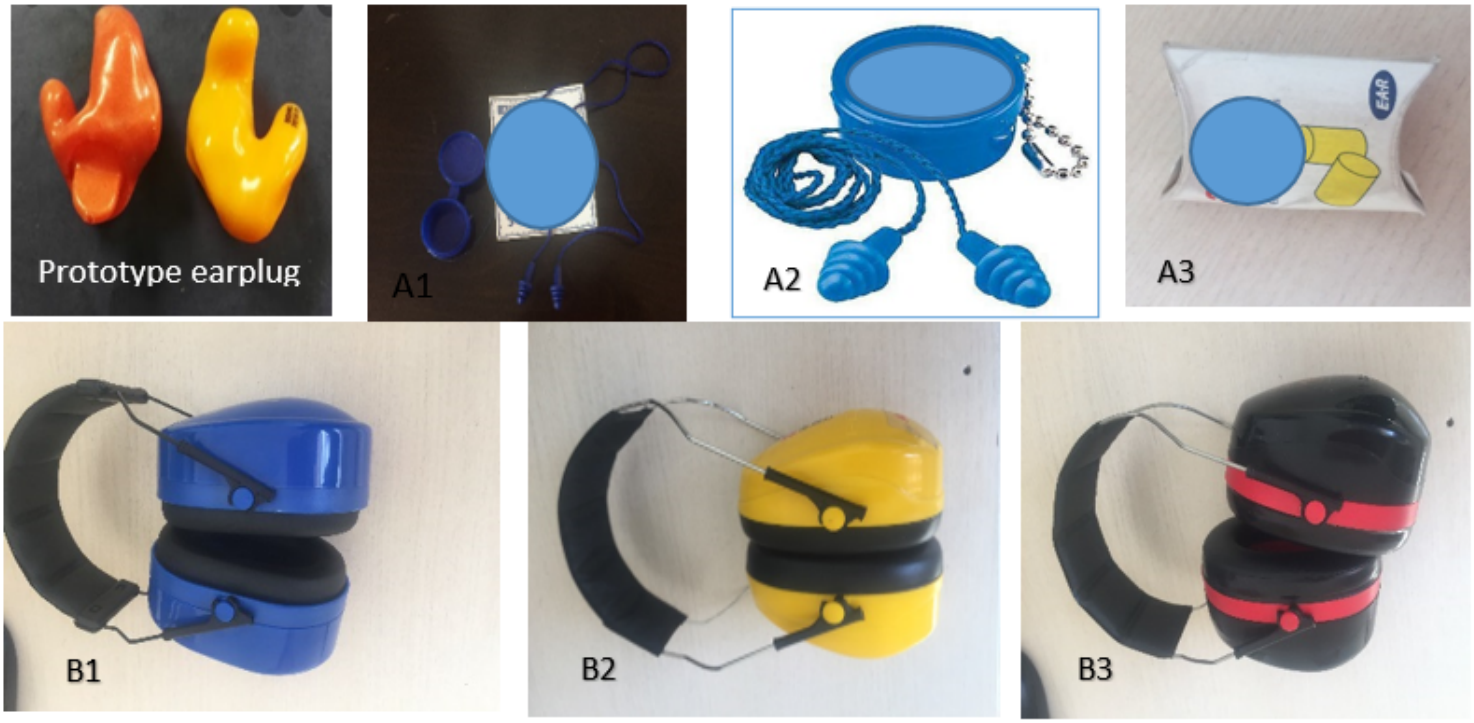

Figure 1

The HPDs types investigated in this study.