ARTICLE IN PRESS

Safety and Health at Work xxx (2017) 1–7

Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.org

Original Article

Individual Fit Testing of Hearing Protection Devices Based on Microphone in Real Ear

Azam Biabani [1], Mohsen Aliabadi [1,*], Rostam Golmohammadi [1], Maryam Farhadian [2]

[1] *Department of Occupational Hygiene, School of Public Health and Researches Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran*

[2] *Department of Biostatistics, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran*

A R T I C L E I N F O

Article history:
Received 25 June 2016
Received in revised form
23 October 2016
Accepted 8 March 2017
Available online xxx

Keywords:
fit testing
hearing protection device
microphone in real ear
noise reduction rating

A B S T R A C T

Background: Labeled noise reduction (NR) data presented by manufacturers are considered one of the main challenging issues for occupational experts in employing hearing protection devices (HPDs). This study aimed to determine the actual NR data of typical HPDs using the objective fit testing method with a microphone in real ear (MIRE) method.

Methods: Five available commercially earmuff protectors were investigated in 30 workers exposed to reference noise source according to the standard method, ISO 11904-1. Personal attenuation rating (PAR) of the earmuffs was measured based on the MIRE method using a noise dosimeter (SVANTEK, model SV 102).

Results: The results showed that means of PAR of the earmuffs are from 49% to 86% of the nominal NR rating. The PAR values of earmuffs when a typical eyewear was worn differed statistically ($p < 0.05$). It is revealed that a typical safety eyewear can reduce the mean of the PAR value by approximately 2.5 dB. The results also showed that measurements based on the MIRE method resulted in low variability. The variability in NR values between individuals, within individuals, and within earmuffs was not the statistically significant ($p > 0.05$).

Conclusion: This study could provide local individual fit data. Ergonomic aspects of the earmuffs and different levels of users experience and awareness can be considered the main factors affecting individual fitting compared with the laboratory condition for acquiring the labeled NR data. Based on the obtained fit testing results, the field application of MIRE can be employed for complementary studies in real workstations while workers perform their regular work duties.

1. Introduction

The objective of an effective hearing conservation program is to minimize the health risks associated with noise exposure, and to prevent hearing loss. One of the main elements of this program is the provision of suitable hearing protection devices (HPDs) to workers exposed to industrial noise and monitoring their suitable usage [1,2]. HPDs are commonly used during the short-term period before the noise is effectively reduced by implementation of engineering controls, or when engineering or administrative controls are not feasible [3,4]. The willingness of workers to use HPDs as passive earmuffs is associated with some important factors such as worker preference and their efficiency. Unreliable nominal noise reduction data presented by the devices are considered the main barrier to rely on hearing protectors as an effective noise control measure. Numerous studies have reported that the reliability of the labeled data to estimate the real noise attenuation of HPDs is poor [5,6].

The noise reduction rating (NRR) is a single-number, laboratory-derived rating that the US Environmental Protection Agency proposed to be shown on the label of each hearing protector. The National Institute for Occupational Safety and Health (NIOSH) proposed the derating method to compensate for known differences between the laboratory-derived noise attenuation values and the noise protection provided by a hearing protector in the real world. Based on the recommended protocol, the labeled NRRs shall

* Corresponding author. Department of Occupational Hygiene, School of Public Health and Researches Center for Health Sciences, Hamadan University of Medical Sciences, P.O. Box 4171-65175, Postal code: 6517838695, Fahmideh Ave, Hamadan, Iran.
E-mail addresses: mohsen.aliabadi@umsha.ac.ir; mohsen_ohse@yahoo.com (M. Aliabadi).

2093-7911/$ – see front matter © 2017, Occupational Safety and Health Research Institute. Published by Elsevier. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
http://dx.doi.org/10.1016/j.shaw.2017.03.005

be derated as follows: (1) earmuffs—subtract 25% from the manufacturers' labeled NRR; (2) formable earplugs—subtract 50%; and (3) all other earplugs—subtract 75% from the manufacturers' labeled NRR. Moreover, for calculating the effective noise exposure to the wearer of a hearing protector at the workplace, the Occupational Safety and Health Administration (OSHA) also derates the NRR by 50% for all types of hearing protectors. Therefore, the NRR cannot be used as a measure of field noise attenuation even when various derating schemes are used to account for the differences between the laboratory and real-world NRR [7]. An individual HPD fit-testing method estimates the amount of noise attenuation that a worker achieves from a given HPD in a particular wearing way and at a particular time and determines whether the worker has sufficient noise protection [8,9].

Real-ear attenuation at threshold (REAT) is the gold-standard technique of fit testing presented by ISO 4869-1 [10,11]. REAT, as a subjective method, was performed by evaluating audiometric hearing threshold levels on an individual with (occluded) and without (unoccluded) hearing protectors [10]. The difference between the occluded and unoccluded thresholds in one octave band is equivalent to the noise attenuation or exact insertion loss (IL) in decibels acquired by the HPDs [11]. NRR values for hearing protectors were calculated using ILs in one octave band. One of the main drawbacks of the REAT method is that the measurement of hearing threshold is a time-consuming task. Furthermore, it should be repeated for each ear and can have some differences in the standard deviation values of the attenuation results [9,12]. It should be noted that accurate REAT measurements require individuals with normal hearing and a very quiet booth so that the open-ear thresholds are not masked and contaminated [13]. This method relies on optimum fitting under laboratory conditions and group statistics to predict performance of hearing protector. The calculated noise attenuation rating is therefore generally higher than the measured noise attenuation rating in the field [14].

The recent development of measuring equipment that can determine HPDs' performance under field conditions along with reasonable accuracy and speed has facilitated the individual fit testing. One of the main objective techniques of HPDs fit testing is microphone in real ear (MIRE) [14]. Field application of MIRE (FMIRE) has been also developed to make rapid and accurate fit testing of the HPDs in occupational settings [9,15]. The MIRE technique is performed by placing a microphone in the ear canal to measure the sound level at the eardrum. The noise attenuation of a hearing protector can be determined from the difference of the sound levels in the ear canal with and without HPDs and is termed IL (measured in dB). The MIRE can also be performed through two microphones, one placed inside the ear canal underneath a hearing protector, and the other simultaneously placed outside the ear. In this mode, the noise attenuation is the difference between the sound levels measured simultaneously by the internal and external microphones, and is termed noise reduction (NR; measured in dB) [7].

However, NR levels are different from IL values by factors that are defined as the transfer function of the open ear (TFOE; e.g., IL = NR + TFOE). TFOE is the amplification relative to the undisturbed sound field caused by ear canal and pinna resonances and the effect of head presence. Individual-specific TFOE factors can be measured with MIRE measurements and extracted from the estimated TFOE values for ears mentioned in the international standard method, ISO 11904-1 [7,16].

In general, the MIRE method had greater speed and efficiency than the REAT method. Its results also had smaller frequency-specific standard deviations than the REAT method. It should be mentioned that the MIRE technique is an objective approach that does not depend on the human responses [12,17].

As mentioned earlier, if local individual fit data are not available, the international institutes proposed using the derating methods to compensate for known differences between the labeled noise attenuation values and the real noise protection obtained by a hearing protector [13,18]. In developing countries such as Iran, occupational health experts also reported that unreliable NR data of HPDs are considered the main challenge to achieve an efficient hearing conservation program. This study aims to evaluate the actual NR data of the commercially available HPDs based on the MIRE method. The results of this study can provide local individual fit data and propose the native derating pattern of the HPDs.

2. Materials and methods

Five commercially available earmuff protectors used by Iranian workers in noisy workplaces were selected to assess the actual noise attenuation data under the reference conditions. Based on the ethical and legal considerations, the protectors studied were nominated as manufacturer models A, B, C, D, and E. Thirty workers participated in the study (age, 25 ± 3.5 years). Each worker was asked to sign an informed consent form prior to experiments. Three samples of each earmuff were tested. Each sample was tested for all workers and the measurements were repeated three times. This experimental study was performed according to the recommendations of the standard methods [10,16]. The standards describe the procedure for measuring IL in the MIRE technique and it presents the specifications regarding the participants, instrumentation, test signal, sound field etc. [12,16]. As recommended by American National Standards Institute (ANSI S12.6-2008), a brief training program was conducted for all workers. Moreover, workers fit HPDs themselves without assistance [10]. The experiments were performed in a custom-built acoustic lab at Hamadan University of Medical Sciences (Hamadan, Iran).

2.1. Experimental setup

The test room characteristics included semireverberant space with T60 < 1.6 seconds and low background noise level according to the standards specifications [10]. The MIRE technique was performed by placing a microphone in the ear canal to measure the sound level at the eardrum. In this regard, the microphone is proximal to the ear canal and the probe is in the ear canal. The noise attenuation of a hearing protector can be determined from the difference of the sound levels in the ear canal with and without HPDs and is termed IL (in dB). Schematic of the experimental setup for measuring IL in one octave band is shown in Fig. 1. It should be noted that this figure was reproduced from SV 102+Data sheet 2016 which is available at website: http://www.svantek.com.

Measurements based on the MIRE technique were performed using the SVANTEK SV 102+, Class 2 dual-channel dosimeter (SVANTEK SP. Z O.O., Warsaw, Poland). An SV 25S microphone, Type 2, has been also designed together with SV 102+ dosimeter that specifies methods for the determination of sound level in the ear canal by different lengths of probes, easily controlled and placed in repeatable position. An SV 25S microphone measured sound level in the ear canal by a probe that was placed at the entry of the ear canal. The length of the probe was selected as 16 mm to ensure maximum comfort and to protect from contact with the eardrum [19]. Calibration of the SV 25S microphones was performed with an SV30/SV31 acoustic calibrator. For all real-ear measurements, the proper placement of the probe tube is important. The tip of the probe tube must be placed within approximately 5 mm of the eardrum to avoid standing waves and to assure that the high-frequency components of the response are accurately measured.

Please cite this article in press as: Biabani A, et al., Individual Fit Testing of Hearing Protection Devices Based on Microphone in Real Ear, Safety and Health at Work (2017), http://dx.doi.org/10.1016/j.shaw.2017.03.005