The Risk of Noise on the Hearing Levels of Individuals Working in Orthotic and Prosthetic Sector

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Abstract

Objective: To identify the effect of noise exposure on the hearing threshold of subjects working in the sector of orthotics and prosthetics.

Methods: The hearing threshold of all subjects was tested using a screening audiometer based on the procedure recommended for industrial audiometry.

Results: Subjects working in the sector of orthotics and prosthetics appeared to have noise induced hearing loss as indicated by their hearing threshold and/or by the presence of notch on their audiograms at 4 or 6 kHz. It was also found that longer duration of noise exposure appears to result in worse hearing threshold.

Conclusions: Our results indicate that subjects working in the sector of orthotics and prosthetics are exposed to hazardous noise levels that have negative effects on their hearing. This is why the implementation of a hearing conservation program that prevents further damage for the hearing of those subjects becomes crucial.

Keywords: Occupational Noise, Orthotics and Prosthetics, Noise Induced Hearing Loss, Audiometric Notch.

Introduction

Noise exposure and aging are the most common causes for hearing loss. More specifically, occupational noise is the most common cause for noise induced hearing loss(1). Occupational hearing loss is the hearing loss that results from exposure to high noise levels in work environments(2). It is estimated that the number of individuals who are exposed to hazardous noise levels in their work is 1.1 million; 170,000 of those will develop hearing loss(3). Noise induced hearing loss commonly results in symptoms of lost ability to understand speech and increased difficulties in the presence of noise(2).

Professions that are generally known to subject employees to noise induced hearing loss are associated with noise levels that are equal to or more than 85 dB(2). In these situations, the use of personal hearing protective equipment (PHPE) becomes

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crucial\(^{(2)}\). In fact, the use of PHPE has become obligatory in many countries\(^{(2)}\). It is also important to perform an annual hearing test for all employees who are regularly exposed to occupational noise. This will help in detecting any hearing and alarms to the need to provide any further protection\(^{(3)}\).

According to the National Institute for Occupational Safety and Health (NIOSH), occupational noise levels should be below 85 dBA when subjects are exposed to it for 8 hours daily. NIOSH has also determined a 3 dBA “exchangeable rate” which indicated that if the noise level was raised by 3 dBA the exposure duration should be reduced to the half. For example, the duration for exposure to 88 dBA should not be more than 4 hours and so. It should be noted however that exposure to noise levels that exceed the limits set by NIOSH on daily basis subject the individual to the risk of noise induced hearing loss\(^{(3)}\).

Exposure to hazardous noise levels initially result in temporary threshold shift (TTS). TTS normally resolves in a time period of 16 to 48 hours\(^{(4)}\). However, if no sufficient time is allowed for it to recover, repeated occurrence of it may develop into a permanent hearing damage\(^{(1)}\). TTS has been known to precede permanent threshold shift in subjects who are regularly exposed to noise\(^{(4)}\). On this basis, the presence of a TTS is considered as a risk factor for the development of a permanent noise induced hearing loss. Noise induced hearing loss develops over a period of 10 to 15 years of extensive noise exposure\(^{(3)}\). After this, the rate of hearing loss development decreases as the threshold becomes worse\(^{(4)}\).

The hearing loss that results from noise exposure is sensorineural and is usually bilateral. The audiogram is characterized by the presence of a dip (called notch) at 4 kHz\(^{(3)}\). Sometimes the notch occurs at 3 or 6 kHz as well depending on different factors such as the size of the external auditory canal or the frequency of the noise\(^{(4)}\). As the hearing loss becomes more severe, the notch becomes deeper to include 2 and 8 kHz. When this happens, adults’ ability to comprehend speech further deteriorates\(^{(3)}\).

Sensorineural hearing loss that results from noise destroys the outer hair cells in the cochlea. In this case, the only management to be provided is hearing aids and any other assistive listening devices. However, despite the development that has been occurring in hearing aid technology, there is not any device that is capable of returning the hearing ability to its original condition. As a result, the protection from the possibility of acquiring hearing loss might be the best management\(^{(2)}\).

Hearing loss has a massive impact on man’s quality of life\(^{(2)}\); for instance workers’ abilities to perform properly in their work environment would be affected. That is, the presence of a hearing loss may prevent them from the ability to hear alarm signals, understand speech and to localize sounds\(^{(3)}\).

This makes the early detection of noise induced hearing loss through hearing screening crucial. During screening, the presence of a threshold shift as small as 10 dB might act as a red flag for the potential of a more severe progressive hearing damage\(^{(5)}\). Additionally, the occurrence of a TTS and tinnitus are other risk factors for a permanent hearing loss\(^{(6)}\).

In Jordan, the workers in the sector of orthotics and prosthetics are regularly exposed to loud noises produced by the machinery used in the production of the assistive devices. To our knowledge, the workers in this sector and the students studying this field in the University of Jordan do not use any protective hearing devices. This is why it is suspected
that this group of people are at risk of developing noise induced hearing loss. This is especially for individuals who have been working in this sector for a longer period of time. Therefore, the aims of this study are:

1- To investigate the presence of hearing loss in individuals who work in the sector of orthotics and prosthetics.
2- To investigate the relationship between the number of working years and hearing threshold.

Materials and Methods

Subjects
The study was carried on 15 employees from Al Basheer hospital, Amman, Jordan who have been working there for a time period of 3 to 20 year. The study was also conducted on 31 orthotic and prosthetic undergraduate students at the University of Jordan. 13 of them were 3rd year students and the other 18 were 4th year students. As it is unexpected to observe an evident effect for noise exposure on students due to the limited exposure duration and thus they can be considered as having normal hearing, the test was also carried on matching age and gender control group of subjects.

Consent
All subjects completed a form indicating their willingness to participate in the study before commencing the data collection.

Equipment
- Otoscope (Riester, Germany).
- Screening audiometer (GSI 67, Entomed, Sweden) coupled to TDH39 headphones.

Procedure
A sound level meter was not available to measure the noise level. Therefore, the noise level was estimated based on the “Rule of thumb”\(^1\). This method estimates the level of the noise in the work place based on the perceived difficulty of being heard in the work place. Workers in both of Al Basheer hospital and the University of Jordan indicated that they experience difficulty or have to shout when trying talk to somebody who is one 1 meter away from the machine. Based on the rule of thumb, the level of noise in both places is around 90 dBA.

After obtaining the consent from subjects, they completed a form asking about the following aspects: age, gender, the number of working hours, number of working days, how many years they have been working in their current job, the presence of other sources of noise exposure, family history of hearing loss.

Otoscopy was performed on all subjects. Based on the procedure recommended for industrial audiometry\(^1\), the hearing threshold of all subjects was then tested at 0.5, 1, 2, 3, 4, 6, and 8 kHz frequencies\(^1\). Hearing threshold is defined as “the lowest sound levels that a listener can detect”\(^7\). The hearing threshold is measured using dB HL unit. In this scale (dB HL), 0 dB HL represents the average hearing threshold of normal hearing individuals\(^7\). However, in clinical practice, individuals with hearing threshold below 20 dB HL are considered to have normal hearing. Accordingly, lower hearing threshold values are indicative of better hearing abilities when compared to higher hearing threshold values.

The testing was done on a Sunday morning

\(^1\) The procedure was performed based of the BSA recommended procedures. See: Pure tone air and bone conduction threshold audiometry with and without masking in: http://thebsa.org.uk/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=16
to ensure that subjects had a minimum of 48 hours free of noise exposure to limit the possibility of the presence of a TTS. The procedure of taking the case history, performing otoscopy and audiometry took approximately 20 minutes per subject.

Data Analysis

To assess the level of damage for each subject, results were categorised based of the Health and Safety Executive (HSE) categorization scheme\(^8\). In this method, the audiometric threshold of each subject at the frequencies 1, 2, 3, 4, 6, and 8 kHz are added together. The sum of these thresholds is then categorized as normal, warning or referral level. Subjects who have a thresholds’ sum that is categorised under warning level can be considered as having a mild hearing impairment when compared with normal subjects with similar age and gender, and this impairment might act as a red flag for the possibility of further damage. Subjects who have a thresholds’ sum that is categorised under referral level are considered to have poor hearing that needs further investigation to determine its extent.

Results

The results for all subject groups are shown in table 1.

4\(^{th}\) years students

![4th year right ear](Figure 1. The mean for the right ear hearing thresholds of 4\(^{th}\) year orthotic and prosthetic students and the control group. In this plot, the horizontal axis represents the different frequencies at which hearing was tested. The vertical axis represents the hearing threshold in dB HL.)
Table 1. Subjects’ classification based on HSE categorisation scheme

<table>
<thead>
<tr>
<th></th>
<th>Bilateral normal</th>
<th>Bilateral warning level</th>
<th>Bilateral referral level</th>
<th>Unilateral warning level</th>
<th>Unilateral referral level</th>
<th>Warning in one ear referral in the other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al Basheer Hospital</td>
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<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>4th year students</td>
<td>15</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3rd year students</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Figures 1 and 2 show a comparison between the thresholds of 4th year students and their control group in the right and left ear respectively.

In figure 1, there is a noticeable difference in both groups’ right ear thresholds particularly at 6 kHz (note that lower thresholds represents better hearing abilities). This was also evident in the notches that were observed on the audiograms of 4th year students.

Figure 2 also shows a difference in the left ears’ thresholds of both groups that is also most evident at 6 kHz.

Independent t-test was carried out to identify any significant difference in thresholds. Results indicated a significant difference in the left ears’ thresholds at 6 kHz only ($p < 0.05= 0.016$).

3rd year students
Figures (3 and 4) shows a comparison between the thresholds of 3rd year students and their control group in the right and left ear respectively.

**Figure 3.** The mean for the right ear hearing thresholds of 3rd year orthotic and prosthetic students and the control group. In this plot, the horizontal axis represents the different frequencies at which hearing was tested. The vertical axis represents the hearing threshold in dB HL.

**Figure 4.** The mean for the left ear hearing thresholds of 3rd year orthotic and prosthetic students and the control group. In this plot, the horizontal axis represents the different frequencies at which hearing was tested. The vertical axis represents the hearing threshold in dB HL.
Figures 3 and 4 also show a noticeable difference in the thresholds of both groups; this difference is most obvious at 1 kHz.

Independent t-test was carried out to identify any significant difference in thresholds. Results indicated a significant difference in the left ears’ thresholds at 1 kHz only ($p < 0.05 = 0.009$).

**Number of working years and hearing threshold**

The correlation between the number of working years and the hearing thresholds at all frequencies was examined using Pearson correlation. A significant correlation was identified between the number of working years and the hearing thresholds at 4 kHz ($r = 0.641$, $p < 0.05 = 0.01$) and 6 kHz ($r = 0.737$, $p < 0.05 = 0.002$) in the left ear. Figures 6 and 7 show this correlation.

**Discussion**

Results of the study revealed that the noise exposure appeared to result in hearing impairment for most of the subjects tested. Hearing impairment was more observable in the group of subjects who were exposed to noise for longer durations. The duration of noise exposure does not refer only to number of hours in which the subjects is exposed to noise at each occasion of exposure, but it also refers to the total period of time during which the subjects has been working in the profession$^{(1)}$.

In our study, all of the subjects working in Al Basheer hospital (who has been working in this field for a longer period of time) had hearing thresholds that can be categorized under either the warning or referral level, only one subject had normal hearing in both ears (notably, this subject had minimal number of
working years). Besides, the presence of a notch at 3, 4 or 6 kHz was also obvious in a large number of the audiograms, which indicates the presence of a noise induced hearing loss.

![Graph showing the relationship between hearing threshold and number of working years at 6 kHz]

**Figure 6. The relationship between the hearing threshold and the number of working years at 6 kHz**

When considering 4th year students, only 3 subjects had hearing thresholds that can be categorized under either warning or referral level. The rest had normal hearing. However, it is noticeable from their audiograms that their hearing thresholds were slightly worse than what it is expected for individuals in their age range. In fact, a large number of them had hearing thresholds that were borderline for being categorized under the warning level (1 to 3 dB difference). In addition, the presence of a notch in a large number of their audiograms at 4 or 6 kHz was alarming. Consequently, we decided to collect data from a matching age and gender group.

As shown in figures (1 and 2) the difference in threshold values was apparent at almost all frequencies. Results of the statistical analysis, however, indicated a significant difference between the two groups only at 6 kHz; which is the frequency where the notch was noticed in a large number of the audiograms. Noise induced hearing loss commonly results in a notch at 4 kHz. Nevertheless, sometimes a notch is seen at 6 kHz in the early stages; but over time, the effect of noise becomes more obvious at 4 kHz\(^9\). Notably, this finding was in the left ear only. This may be because the orthotic and prosthetic workshop machinery has to be used in a specific standing position. In this position, the student’s left ear is closer to noise source (the machinery electric motor). The presence of a noise induced hearing loss in these students’ audiograms is an alarming signal that
indicates that they are exposed to harmful noise levels. Exposure to these noise levels put them at a risk of developing further hearing damage if no intervention is provided.

Data was also collected from another control group for 3rd year students. The difference in thresholds between both groups was also obvious at all frequencies but only statistically significant at 1 kHz in the left ear. Nevertheless, there were no obvious notches in any of 3rd year students’ audiograms. This might be because the hearing loss is still in the very early stages where a notch is not apparent yet.

Results of the correlational analysis between the number of working years and hearing thresholds indicated a significant effect for the number of working years at 4 and 6 kHz in the left ear only. This supports our assumption that increased duration of noise exposure results in more hearing damage. It also agrees with the fact that 4 and 6 kHz are the frequencies that are more susceptible to the damage caused by the noise exposure. The relationship was observed in the left ear only for the same reason discussed for 4th year students.

Conclusion

1- Results of the study indicated that individuals working in the sector of orthotics and prosthetics are likely to be at risk of developing noise induced hearing loss. The risk increases with increased duration of noise exposure.

2- Universities that teach programs in which enrolled students are exposed to high noise (such as orthotic and prosthetic students) must implement a hearing conservation program\(^{(1)}\). This program aims at protecting the hearing of those students through controlling the noise produced by the machines, providing an appropriate design for the work place, and the provision of appropriate personal hearing protection and regular hearing tests. The hearing conservation program should be directed to students from the first year of the study until they graduate.

References

Noise Risk on Hearing Levels ... Sara Alhanbali, Mohammad Sobuh, Zainab Al Addasi

wearing hearing protection and how these might be changed. Sudbury: HSE Books, 2002.


11. Hughson GW, Mulholland RE, Cowie HA. Behavioural studies of people's attitudes to

خطر الضوضاء على مستويات سمع الأشخاص الذين يعملون في مجال
الأطراف الاصطناعية والأجهزة المساندة

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الملخص

الهدف: تجعلن أثر التعرض إلى الضوضاء على مستوى سمع الأشخاص الذين يعملون في مجال الأطراف الاصطناعية والأجهزة المساندة

وشملت غالبًا على الدراسة.

الطريقة: تم تحديد مستوى سمع الأشخاص الذين خضعوا للدراسة باستخدام جهاز فحص السمع (اختبار صغير توتر الصوت) وتأتي

الإجراء الموسمي لفحص سمع الأشخاص الذين يعملون في بيئة صناعية.

النتائج: تبين أن الأشخاص الذين يعملون في مجال الأطراف الاصطناعية والأجهزة المساندة يعانون من فقدان في السمع ناتج عن

الضوضاء، وفقًا لما أشارت إليه فحوصات عينة السمع التي أجريت لهم و/أ وجود اختلاف في الرسم البياني الخاص بفحص السمع على

ترددات 4 أو 6 كيلو هرتز. كما تبين أن التعرض إلى الضوضاء لفترات أطول له أثر أكبر في ضعف مستوى السمع.

كما تشير النتائج التي تم التوصل إليها إلى أن الأشخاص الذين يعملون في مجال الأطراف الاصطناعية والأجهزة المساندة يتعرضون

لمستويات خطيرة من الضوضاء تؤثر بشكل سلبي في سمعهم، مما يدعو إلى ضرورة تنفيذ برنامج خاص بالحافز على السمع، بحيث يضع

حذاء الأطر السلي في ضعف هذه الضوضاء.

الكلمات المفتاحية: الضوضاء، الأطراف الاصطناعية والأجهزة المساندة، خطر الضوضاء على مستويات سمع الأشخاص.