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RESEARCH ARTICLE

Occupational Exposure to Noise and Age-related Hearing Loss in an Elderly Population of Southern Italy

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Abstract:

Background:

Age-Related Hearing Loss (ARHL) is a gradual and irreversible age-dependent decline in auditory function. There is still no consensus on the long-term functional effects of noise exposure on ARHL.

Objective:

This study aimed to compare the prevalence of ARHL in an elderly population occupationally exposed to noise in a non-exposed population.

Methods:

The population was divided into two groups: a group of 482 subjects professionally exposed to noise for over 10 years and a group of 1129 non-exposed subjects. Among the exposed subjects, a subgroup of 298 who worked for over 10 years in the glassware industry was selected. All the participants underwent a thorough otorhinolaryngological examination.

Results:

The presence of ARHL was found in 81% of exposed subjects and in 4% of non-exposed subjects. In the sub-group of glassware workers, the prevalence was 88%. The statistical analysis showed a significant association between previous occupational exposure to noise and ARHL (OR = 1.09; 95% CI = 1.067-1.124; p = 0.0012) and between exposure to the glassware industry and ARHL (OR = 1.89; 95% CI = 1.78-1.96; p = 0.006).

Conclusion:

Consistent with recent studies, we found a significantly higher prevalence of ARHL among workers exposed to noise; however, further studies are needed to support these findings.

Keywords: Age-related hearing loss, Glassware, Noise, Noise-induced hearing loss, Occupational exposure, Workers.

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1. INTRODUCTION

The environmental and occupational health risk factors due to exposure to chemical, carcinogenic, physical and biological agents are heterogeneous [1 - 20].

Noise is a physical agent that causes noise-induced hearing loss (NIHL). NIHL has long been recognized as an occupational disease. It is the consequence of overexposure to loud noise, characterized by a permanent increase in auditory thresholds [21 - 25]. It has been suggested that 12% or more of the global population is at risk of hearing loss from noise, which equates to well over 600 million people [26]. The World Health Organization estimated that one-third of all cases of hearing loss can be attributed to noise exposure [27].

Age-related hearing loss (ARHL), or presbycusis in the human clinic, is a gradual and irreversible age-dependent decline in auditory function, which is reflected in a progressive increase in auditory thresholds, mainly in the high-frequency range [28].

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Subjects present degraded frequency discrimination and limitations in speech comprehension tasks [29 - 34]. ARHL is a well-recognized condition in older age, with a high prevalence in the general population of approximately 20% in individuals over 65 years old but increasing to 65% in individuals over 85 years old [35]. Both age-related hearing loss (ARHL) and noise-induced hearing loss (NIHL) may share pathophysiological mechanisms in that they are associated with excessive free radical formation and cochlear blood flow reduction, leading to cochlear damage [36]. They can be distinguished only on the basis of the period in which they occur and the specific risk factors with which they are associated. NIHL and ARHL are often presented simultaneously and represent a *continuum* in which the former becomes a powerful causal risk factor for the latter. Therefore, it is possible that occupational noise exposure may add to cochlear ageing mechanisms, having an impact on the onset and/or progression of ARHL. Nevertheless, although there is substantial information on noise and ageing, there is still no consensus on the long-term functional effects of noise exposure on ARHL [37].

Therefore, the aim of the present study was to evaluate the prevalence of ARHL in an elderly population occupationally exposed to noise compared with a non-exposed population residing in Castellana Grotte, a small town in the Apulia region of southern Italy, and the surrounding area.

2. MATERIALS AND METHODS

Between January 2013 and August 2017, a sample of 1611 subjects (769 males, 842 females; average age 73.8 years, SD ± 6), living independently or institutionalized, was randomly selected from the electoral rolls of eight Italian municipalities after stratification for age and gender. All subjects are part of "The Great-AGE Study", an on-going population-based study on ageing conducted in Castellana Grotte, a small town in the Apulia region, southern Italy [38]. The study population was divided into a group of subjects exposed professionally to noise for a period of less than 10 years or not at all (n = 1129) and a group of subjects professionally exposed to noise for over 10 years (n = 482). Among these, a subgroup of 298 subjects who worked for over 10 years in the glassware industry in Castellana Grotte and who were professionally exposed to noise levels were selected, as shown by environmental monitoring findings in Table **1**.

Voluntary informed consent was obtained from the subjects and/or their relatives before enrolment. All subjects underwent an otorhinolaryngological examination at the National Institute of Gastroenterology-Research Hospital IRCCS 'Saverio de Bellis' in Castellana Grotte, which consisted of recording medical history to reconstruct the following: occupational exposure to noise and ototoxic substances; the presence of tinnitus; otoscopy with occluding cerumen removal; tympanometry; and stapedial reflex to discriminate hearing loss from other inner-ear pathologies. Finally, an assessment of auditory function was performed using tonal audiometry and language.

Pure tone audiometry was performed in a standardized manner, and the identification of synthetic sentences with ipsilateral competing message (SSI-ICM), adapted and validated in the Italian language, was performed in a soundproofed room.

Air conduction thresholds for both ears were registered and stored in a database. The following frequencies were tested: 0.5 kHz, 1 kHz, and 2 kHz. The ascending method was used, and ISO 389 and ISO 8253-1 standards were applied. The tests were performed in quiet office rooms in the same building. Hearing loss is established on the basis of the classification of four stages of deficit in the best ear, identified through the BIAP scale [39]. Trained clinical audiologists performed the tests (air and bone conduction thresholds). Masking was performed when applicable.

The purpose of environmental monitoring in the glassware industry was to assess the exposure to noise of workers. The measurements were carried out by a technician competent in environmental acoustics and were performed during the ordinary working day through the use of a "Larson Davis" integrator/analyser according to ANSI class I standards. The calibration was performed before and after the execution of the measurements with a "Larson Davis" calibrator conforming to the ANSI class I standards for acoustic calibrators (calibration

Table 1. Noise monitoring in glassware.

Job	LEX, 8 h (dBA)	PPE Type	LEX, 8 h with PPE (dBA)	PPE Effectiveness
Manufacturing workshop	100.2 – 99.7	Earplugs "Ear classic soft"	74.5 – 73.2	Good
Maintenance workshop	97.6 – 93.4	Headphones "Peltor H520A"	74.2 – 71.8	Good
Oven	90.8	Earplugs "Ear classic soft"	73.2 - 72.7	Good
Measuring systems analysis	89.4 -89.1	Headphones "Peltor H520A"	72.3 – 71.3	Good
Molds	86.5 – 79.7	Earplugs "Ear classic soft"	65.8 – 73.8	Acceptable
Quality check	84.2	Earplugs "Ear classic soft"	66.7	Acceptable
Electrical workshop	83.4 – 79.4	Headphones "Peltor H520A"	74.5 - 71.9	Good
Shovel attendant	81.0	Earplugs "Ear classic soft"	79.2	Acceptable
Forklift driver	73.3 – 72.3	-	-	-
Concierge clerk	64.5	-	-	-

values within the tolerance limits of 0.5 dB established by the UNI9432: 2011 standard).

The level of daily exposure to noise among workers was evaluated through the following phases: the completion of phonometric surveys of equivalent levels in dB (A) and peak acoustic pressure in dB (C) at workstations; the acquisition of the daily exposure times of workers; and the calculation of daily exposure levels (Lex, 8 h) using specific software (Noise and Vibration Works). Furthermore, to assess the availability of hearing personal protective equipment (PPE) appropriate for workers' needs, the effectiveness of the PPE in use was verified using special software (Noise and Vibration Works) to calculate the level of daily exposure, which takes into account the attenuation characteristics of the device used.

Equivalent-level measurements were performed in compliance with the UNI 9432: 2011 standard; in particular, the microphone was positioned and oriented to provide the best approximation of the worker's noise exposure without changing the safety conditions and hindering the normal performance of daily work activities.

The type of noise considered is mainly stationary. In accordance with the UNI 9432: 2011 standard, the measurement duration was limited to the time necessary to obtain stabilization within ± 3 dB (A) of the equivalent-level reading of the measurement instrument; in any case, this length of time was not less than 60 seconds. The daily exposure levels were calculated using specific software by entering the values of the equivalent level measured in the workstations and the relative exposure times. Daily exposure levels were calculated by taking into account the use of auricular PPE worn during the activity.

The association between presbycusis and noise was evaluated through the Spearman correlation coefficient and with logistic regression adjusted for age, sex and education.

3. RESULTS

The noise levels measured by environmental monitoring in the glassware industry are shown in Table **1**).

A total of 439 (27%) of the 1611 subjects participating in the study showed the presence of ARHL (Table **2**). In the group of 482 subjects professionally exposed to noise for over 10 years, 389 (81%) showed the presence of ARHL.

The presence of ARHL was found in 50 (4%) of the 1129 subjects exposed professionally to noise for less than 10 years or never exposed. In the subgroup of 298 subjects who worked for over 10 years in the glassware industry, ARHL was found in 262 subjects (88% prevalence) (Table **3**).

The statistical analysis showed a significant association ($p < 0.001$) between previous occupational exposure and ARHL (OR = 1.09; 95% CI = 1.067-1.124; $p = 0.0012$) and between exposure to the glassware industry and ARHL (OR = 1.89; 95% CI = 1.78-1.96; $p = 0.006$) (Table **4**).

4. DISCUSSION

The results of the environmental monitoring of noise in the glassware industry show that the manufacturing department has the highest noise levels due to the presence of machines in which the hollow glass is printed. Warehouses are areas characterized by negligible noise, levels are well below 80 dB, and workshops are mainly low-noise areas. The attenuation of the noise, guaranteed by the PPE, limits the exposure of the workers to levels below the occupational exposure limit value of 87 dB (A), as established by Italian law (Legislative Decree 81/2008). However, it is necessary to consider that the exposed subjects of the study worked in the glassware industry during the years in which the PPE were not supplied to the personnel in service, were not adequate or were not used. For this reason, it is legitimate to assume that the workers in the glassware industry have been exposed to noise levels that are likely to cause damage to the hearing apparatus.

Our study has some limitations. First, the cross-sectional study design did not allow us to make a comparison with the ISO 1999:2013 standard for estimating noise-induced hearing loss in occupationally exposed workers [40]. Second, environmental noise monitoring in the glassware industry was conducted many years after the period in which our study population worked. Therefore, we have no direct information about the noise levels or the use and efficiency of PPE during the years in which our exposed group worked.

Table 2. Prevalence of age-related hearing loss.

ARHL	TOTAL (n (%))
No	1172 (73%)
Yes	439 (27%)
TOTAL	**1611 (100%)**

Table 3. Prevalence of age-related hearing loss in noise-exposed individuals.

ARHL	Never exposed/exposed < 10 years	Exposed > 10 years	Glassware > 10 years
No	1079 (96%)	93 (19%)	36 (12%)
Yes	50 (4%)	389 (81%)	262 (88%)
TOTAL	**1129 (100%)**	**482 (100%)**	**298 (100%)**

Table 4. Logistic regression adjusted for sex, age and education.

	OR	Std. Error	p value	95% CI
Exposed > 10 years	1.09	0.14	0.0012	(1.067 - 1.124)
Glassware > 10 years	1.89	0.32	0.006	(1.78 – 1.96)

The results of our study, even with these limitations, show a higher prevalence of ARHL in the group of occupationally noise-exposed subjects than in the group of non-exposed subjects. Our study is one of the few aiming to evaluate the prevalence of ARHL in a large population occupationally exposed to noise compared with a non-exposed population (1611 subjects). In a recent study on 4988 subjects, Kovalova *et al*. showed statistically significant differences in hearing loss at various frequencies in various male age groups. The results suggest that males at

occupational risk have a higher auditory threshold than those at no risk. The highest rates of statistically significant differences at frequencies measured by audiometry were seen in males aged 60 to 74 years, followed by the 45 to 59 age group [41]. In contrast, the results of another study show no significant differences in hearing decline at any frequency in those from 70 years to 75 years of age between occupational noise-exposed and non-exposed subjects of either gender [42]. In a recent Brazilian study on dance teachers, no statistically significant differences in hearing loss between the participants exposed and those not exposed to occupational noise were found. This finding may have been affected by the small sample size (32 cases and 32 controls) [43]. Another study examining hearing loss in people at risk of exposure to occupational noise (12,055 rail workers) was conducted in Norway by Lie *et al*. [44]. The findings showed that the audiometric curves in women exposed and those not exposed to occupational noise were virtually unchanged.

CONCLUSION

In conclusion, the results of our study show a significant association between occupational exposure and ARHL. This association is stronger for those with exposure to the glassware industry. It is therefore possible to hypothesize that occupational exposure to noise may play a role in increasing the prevalence of ARHL in older age. However, in the scientific community, there is still no consensus on the long-term functional effects of noise exposure on ARHL [37]. In a recent literature study, the authors show how repeated short-duration loud-sound overstimulation accelerates the time course of ARHL in an animal model of auditory ageing [45].

Although the nature of interactions between noise and auditory ageing is questionable, the prevailing theory is that noise modifies the onset and/or progression of ARHL [32, 37, 46 - 49].

In the Framingham study, a combined effect of noise and ageing has been described [45]. They found that elderly men with noise notches in their audiograms had a reduced progression of hearing loss over time at 3 kHz, 4 kHz, and 6 kHz and an accelerated rate of hearing loss in frequency areas adjacent to noise-damaged frequencies, especially at 2 kHz. In men without typical noise notches, this pattern was reversed. This finding could not be reproduced by Lee *et al*. [50, 51].

Most of these studies are based on single noise exposure or short-term noise stimulation protocols, but humans are exposed daily to multiple loud sounds, so additional research is needed to better recreate these noise conditions.

In the future, major repercussions can be expected because while occupational noise tends to decrease in developed countries, it remains a major public health problem worldwide [52]. The population groups at risk are mostly teenagers and young adults, especially due to the use of personal portable audio devices, such as smartphones and MP3 players [23], which represent a long-term potential health risk for the development of premature presbycusis with all its consequences.

LIST OF ABBREVIATIONS

ARHL = Age-Related Hearing Loss;

NIHL = Noise-Induced Hearing Loss;

SSI-ICM = Identification of Synthetic Sentences with Ipsilateral Competing Message;

PPE = Personal Protective Equipment.

AUTHORS' CONTRIBUTIONS

LV, DC and RS conceived and designed the work; DC, LDM and AC performed the work; DC, RS analysed the data and interpreted the results; and LV, DC, LDM, AC, ESSC, FM, FB and DMC wrote and revised the manuscript. All authors read and approved the final manuscript.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval is not necessary because all medical and instrumental examinations were performed according to Italian law concerning the protection of workers exposed to occupational risks (D.Lgs. 81/2008).

HUMAN AND ANIMAL RIGHTS

This study did not involve experiments on humans or animals.

CONSENT FOR PUBLICATION

Informed and written consent was obtained from all participants. All subjects were informed that data from the research protocol would be treated in an anonymous and collective way, with scientific methods.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author [L.V], upon reasonable request.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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