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Self-reported hearing performance in workers exposed to solvents

Autoavaliação de funções auditivas em trabalhadores expostos a solventes

ABSTRACT

OBJECTIVE: To compare hearing performance relating to the peripheral and central auditory system between solvent-exposed and non-exposed workers.

METHODS: Forty-eight workers exposed to a mixture of solvents and 48 non-exposed control subjects of matched age, gender and educational level were selected to participate in the study. The evaluation procedures included: pure-tone audiometry (500 – 8,000 Hz), to investigate the peripheral auditory system; the Random Gap Detection test, to assess the central auditory system; and the Amsterdam Inventory for Auditory Disability and Handicap, to investigate subjects' self-reported hearing performance in daily-life activities. A Student t test and analyses of covariance (ANCOVA) were computed to determine possible significant differences between solvent-exposed and non-exposed subjects for the hearing level, Random Gap Detection test and Amsterdam Inventory for Auditory Disability and Handicap. Pearson correlations among the three measures were also calculated.

RESULTS: Solvent-exposed subjects exhibited significantly poorer hearing thresholds for the right ear than non-exposed subjects. Also, solvent-exposed subjects exhibited poorer results for the Random Gap Detection test and self-reported poorer listening performance than non-exposed subjects. Results of the Amsterdam Inventory for Auditory Disability and Handicap were significantly correlated with the binaural average of subject pure-tone thresholds and Random Gap Detection test performance.

CONCLUSIONS: Solvent exposure is associated with poorer hearing performance in daily life activities that relate to the function of the peripheral and central auditory system.

DESCRIPTORS: Hearing Loss, epidemiology. Auditory Perception. Hearing. Solvents, adverse effects. Occupational Exposure. Occupational Risks. Occupational Health.

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RESUMO

OBJETIVO: Comparar o desempenho das atividades diárias relacionadas a funções do sistema auditivo periférico e central entre trabalhadores expostos e não expostos a solventes.

MÉTODOS: Participaram do estudo 96 trabalhadores, sendo 48 expostos a solventes e 48 não expostos, pareados por escolaridade, idade e sexo. Os procedimentos de avaliação incluíram: audiometria de tons puros (500 a 8.000 Hz), para avaliar o sistema auditivo periférico; teste de *Random Gap Detection*, para avaliar o sistema auditivo central; e o *Amsterdam Inventory for Auditory Disability and Handicap*, para estudar a performance em atividades da vida diária que envolvem a audição, por meio de autoavaliação. Teste *t* de *student* e a análise de covariância (ANCOVA) foram utilizados. Foram calculadas as correlações de Pearson entre os resultados dos três testes.

RESULTADOS: Sujeitos expostos a solventes tiveram limiares auditivos significativamente piores na orelha direita que os sujeitos não expostos. Apresentaram também resultados significativamente piores no teste de *Random Gap Detection* e funcionamento autorreportado significativamente mais alterado que os sujeitos não expostos. Foi observada correlação significativa entre os resultados do *Amsterdam Inventory for Auditory Disability and Handicap* e a média binaural dos limiares auditivos e com os resultados do teste de *Random Gap Detection*.

CONCLUSÕES: A exposição a solventes está associada com as dificuldades da vida diária relacionadas com as funções do sistema auditivo periférico e central.

DESCRITORES: Perda Auditiva, epidemiologia. Percepção Auditiva. Audição. Solventes, efeitos adversos. Exposição Ocupacional. Riscos Ocupacionais. Saúde do Trabalhador.

INTRODUCTION

Noise exposure may induce hearing loss and other agents such as organic solvents may be hazardous to the human auditory system. Exposure to a mixture of solvents may induce hearing loss in humans.[19] Millions of workers are exposed to solvents in their workplaces.[6]

A solvent is a liquid used to dissolve other substances. Most solvents are colorless liquids at room temperature, which volatize easily and have strong odors. Solvents are most commonly inhaled in their volatized form and absorbed through the respiratory tract. Organic solvents are widely used around the world and many different industrial processes require their use: in automotive and aviation fuels; plastics industries; as a thinner for paints, lacquers, coatings and dyes; in the manufacture of artificial leather, detergents, medicines, perfumes, fabric and paper coatings, photogravure inks and spray surface coatings; and in insect repellents.[7]

Organic solvents such as toluene, ethyl benzene, styrene and xylene induce toxicity to the outer hair cells (OHCs) of animal cochleae.[2,3,5,16,17] In humans, hearing loss induced by solvents has been found in workers exposed to a mixture of toluene, ethyl acetate and ethanol,[19] and xylene and ethyl acetate.[25] A recent multi-center, cross-sectional study found an association between styrene exposure and poorer hearing thresholds than were predicted by the individuals' age.[22] Human cross-sectional studies have also found dysfunction of the central auditory nervous system (CANS) in workers exposed to a mixture of solvents.[11,23] Fuente et al have shown that workers exposed to a mixture of solvents (toluene, xylene and methyl ethyl ketone) may acquire central auditory dysfunction, as measured through a set of behavioral central auditory processing tests.[11] Other studies have found central auditory effects associated with solvent exposure (mainly toluene) through the use of electrophysiological measures such as the auditory brainstem response[1,27] and the P300 response.[18,26]

In summary, solvents not only adversely affect the sensory organ of the auditory system (cochlea), as noise does, but also affect the central auditory structures.[24] Morata & Lemasters[20] suggested that the adverse auditory effects of solvents are due to a combination of oto-and neuro-toxicity. Oto-toxicity induces OHC dysfunction in the cochlea, whereas neuro-toxicity induces central auditory dysfunction. The main audiological sign of oto-toxicity is poorer hearing thresholds than expected relative to age. Audiological signs of neuro-toxicity may or may not include poorer hearing thresholds, in addition to difficulties localizing the sound source or discriminating sounds, such as speech, even in the presence of normal hearing thresholds. From a functional point of view, solvent-exposed workers are likely to experience difficulties in daily-life listening situations such as understanding speech in the presence of background noise, or when the speech signal is degraded (e.g., in restaurants, social gatherings, church, attending lectures in auditoriums). Despite all the studies conducted in solvent-exposed workers, there is limited understanding of whether solvent-exposed workers report poorer listening performance in daily-life activities, in relation to the functions of the peripheral and central auditory system, than their peers who are not exposed to solvents.

This research aimed to compare hearing performance relating to the peripheral and central auditory system between solvent-exposed and non-exposed workers.

METHODS

A group of 48 solvent-exposed subjects (ages 25 to 51, mean 38.6, standard deviation – SD 7.1) and 48 control subjects with matched educational level (partial secondary studies, completed secondary studies, tertiary studies), age (+/- 5 years) and gender (male) (ages 30 to 55 years, mean 36.8, SD 4.8) without solvent exposure were selected to participate in the study. All subjects resided in Santiago, Chile. Solvent-exposed subjects were selected from two paint-making factories. Workers directly exposed to solvents were selected. All possible research participants from both factories were invited to participate in the study. No single subject refused to take part in the research. The job categories included maintenance engineers, production supervisors, machine operators, quality controllers, assistants, mixers, and hazardous waste handlers. They were exposed to a mixture of solvents (mean length of exposure: 13.5 years) including toluene (mean: 14.3 mg/m^3), xylene (mean: 28.2 mg/m^3), methyl ethyl ketone (mean: 10.8 mg/m^3), and Stoddard solvent (mean: 116.3 mg/m^3). The permissible exposure limits for toluene, xylene, methyl ethyl ketone, and Stoddard solvent in Chile are: 300 mg/m^3, 347 mg/m^3, 472 mg/m^3 and 1,100 mg/m^3, respectively, as an 8-hour time-weighted average concentration. Control subjects were administrative employees of the University of Chile. All solvent-exposed workers were exposed to noise levels of < 85 dBA. No records of occupational noise exposure levels were available for control subjects.

An initial questionnaire was administered to both solvent-exposed and control subjects. This questionnaire addressed subjects' ear history and medical conditions that may be related to the onset of auditory dysfunction, occupational history (e.g., previous jobs exposed to noise, use of solvents, and tenure at each workplace), and non-occupational noise exposure. The questionnaire was utilized to select subjects with an absence of variables related to auditory dysfunction, other than exposure to solvents in the solvent-exposed group. Subjects with a history of repeated otitis media during childhood and/or adulthood, hypertension, diabetes, metabolic diseases, head injury and previous jobs exposed to high intensities of noise were not included.

Bilateral otoscopies were carried out. Subjects with an absence of visible pathologic alteration to the ear canal and tympanic membrane were included in the sample. Tympanometry and pure-tone audiometry (air and bone conduction) were carried out. Subjects with normal type A tympanometric results[13] and either normal hearing or sensorineural hearing loss were included. Subjects with conductive or mixed hearing loss were excluded.

All audiological measurements were conducted in a double-walled sound proofed room. Pure-tone audiometry was carried out to evaluate the peripheral auditory system. Pure-tone air-and bone-conduction thresholds were obtained using an Interacoustics AC33 clinical audiometer with TDH-39P headphones. Air conduction pure-tone thresholds from 500 to 8,000 Hz were tested. The presentation order was as follows: 1,000, 2,000, 3,000, 4,000, 6,000, 8,000 and 500 Hz. The modified Hughson and Westlake procedure[12] described by Carhart & Jerger[4] was used to obtain the hearing thresholds. Bone-conduction pure-tone thresholds from 500 to 4,000 Hz were tested. The presentation order was as follows: 1,000, 2,000, 3,000, 4,000 and 500 Hz. Stimuli were delivered to each mastoid through a Radioear B-71 bone vibrator. The procedure for air-conduction described was used to obtain the bone conduction hearing thresholds.

The Random Gap Detection test (RGD)[14] was used to evaluate the central auditory system, as previously suggested as a test to detect CANS dysfunction associated with solvent exposure.[21] The RGD explores temporal resolution, which is related to the timing encoded in the auditory fibers in response to sound. Temporal resolution has been indicated as one of the aspects of the CANS that are adversely affected by solvent exposure.[8,11] The RGD utilized a compact disc player (LG 7311N) connected to the audiometer mentioned above. A 1,000 Hz calibration tone recorded on the compact disc with the test was used to determine output intensity. Stimuli comprising two tones and clicks with a silent interval between the two stimuli at different durations were presented at 50 dB HL, binaurally.[14] The silent interval (time delay between the onset of one stimulus in comparison to the onset of the other stimulus) between the two tones and clicks ranged from 0 to 40 milliseconds (ms) (0, 2, 5, 10, 15, 20, 25, 30, and 40 ms, randomly presented). This procedure started with the presentation of a practice subtest which uses a 500 Hz tone burst. Four subtests were carried out according to the frequency of the stimuli: 500, 1,000, 2,000 and 4,000 Hz. A practice subtest for click stimuli was performed and the click subtest was carried out. Thus, a total of five subtests were administered for further analyses (RGD 500 Hz, RGD 1,000 Hz, RGD 2,000 Hz, RGD 4,000 Hz and RGD clicks). Subjects were asked to state whether they heard one or two tones in each presentation. Thresholds for each frequency tested and for the click stimuli were obtained by identifying from the score sheet the interval in milliseconds at which the subject consistently commenced detection of two stimuli, instead of one.

The Amsterdam Inventory for Auditory Disability and Handicap (AIADH)[15] was the self-report questionnaire chosen to explore subjects' listening performance for daily-life activities. The AIADH had been previously adapted into Spanish and has been shown to have good internal consistency and test-retest reliability.[9] The AIADH is comprised of 30 question-items. Each question addresses a specific listening activity (e.g., understanding speech in a crowded shop, following a conversation among various speakers during dinner, following a telephone conversation). Each question is accompanied by a picture representing the specific situation that is being considered. Thus the understanding of each question is enhanced by the presence of a pictorial representation of each situation. This makes the AIADH a user-friendly assessment tool that can be easily completed by a respondent, without even the need of an examiner. For each question-item, the person had to indicate how often he can perform the listening activity being addressed, based on a four-item response scale (almost never, occasionally, frequently, almost always). The response scale is scored from 1 (almost never) to 4 (almost always), thus the higher the score, the better the performance. The total score of the AIADH is 120.

Factor analysis of the original version of the AIADH showed the presence of five main factors, interpreted by the authors as five basic auditory disabilities: distinction of sounds, intelligibility in noise, auditory localization, intelligibility in quiet and detection of sounds.[15] Aspects relating to the function of the peripheral auditory system (i.e., sound detection) and central auditory system (i.e., speech discrimination, sound localization) can be explored. Furthermore, 28 of the 30 question-items can be grouped into the four hearing functions proposed by the World Health Organization (WHO) in the International Classification of Functioning, Disability and Health (ICF): detection of sounds, sound discrimination, speech discrimination and sound localization/lateralization.[28] It is also possible to determine listening difficulties under the WHO framework – which may further help to identify activity limitations considered under the same framework. Participants' listening performance for each of the four WHO hearing functions is explored (Table 1).

The 30-item questionnaire and a pencil were given to each subject individually in a quiet room prior to the hearing assessment. The examiner checked the questionnaire and ensured that a response had been given to each question. If any question remained unanswered, the examiner asked the participant to complete that question. No clarification of any question was permitted.

The hearing level of each subject was calculated according to the WHO guidelines for grade of hearing impairment (WHO, 1991,[a] with adaptations from WHO, 1997).[b] The WHO classification of hearing impairment is based on the average pure-tone thresholds at 500, 1,000, 2,000 and 4,000 Hz in the better ear. An average of 25 dB or above at the previously mentioned frequencies in the better ear is considered to be a hearing impairment. The number of subjects with hearing impairment according to WHO was determined for both solvent-exposed and non-exposed subjects. A Student t test was computed to determine possible significant differences between solvent-exposed and non-exposed subjects for the average pure-tone threshold (500, 1,000, 2,000 and 4,000 Hz) for the right and left ear. Considering that solvent exposure mainly affects the high frequency hearing thresholds, the average pure-tone threshold for high frequencies (3,000, 4,000, 6,000 and 8,000 Hz) was calculated for the right and left ears in both groups of participants. The percentage of abnormal audiograms for each group of subjects was calculated, based on the pure-tone average for high frequencies. An abnormal audiogram was defined as the average pure-tone threshold for high frequencies equal to or above 26 dB HL in at least one ear.

Analyses of covariance (ANCOVA) were performed to compare the mean values of the results of the RGD subtests (500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz, clicks) between solvent-exposed and non-exposed subjects. Age was included in the ANCOVA as a covariate. Differences between solvent-exposed and non-exposed subjects and the mean test scores, adjusted for age, were obtained for each group. ANCOVA were performed to compare the mean scores of the four factors (hearing functions, Table 1) and overall score of the AIADH

[a] World Health Organization. Report of the Informal Working Group on Prevention of Deafness and Hearing Impairment Programme Planning. WHO/PDH/91. Geneva; 1991.
[b] World Health Organization. Report of the first informal consultation on future programme developments for prevention of deafness and hearing impairment. WHO/PDH/97.3. Geneva; 1997.

between solvent-exposed and non-exposed subjects. Age was included in the ANCOVA as a covariate. Differences between solvent-exposed and non-exposed subjects and the mean scores for the four hearing functions and overall score of the AIADH, adjusted for age, were obtained for each group.

Pearson correlations were computed among the variables of AIADH overall score, binaural average pure-tone thresholds ([right ear hearing thresholds at 500, 1,000, 2,000 and 4,000 Hz + left ear hearing thresholds at 500, 1,000, 2,000 and 4,000 Hz]/8) and RGD clicks. This was done in order to determine whether the overall score of the AIADH, i.e., the subjects' self-reported performance for the hearing functions in daily-life situations, was correlated with the results of the audiological measures of peripheral hearing (pure-tone audiometry) and central auditory function (RGD).

This study was conducted in compliance with the principles of the World Medical Association Declaration of Helsinki. All research procedures were approved by the Ethics Committee of the Faculty of Medicine, University of Chile.

RESULTS

Solvent-exposed and control-group subjects presented grand mean hearing thresholds better than 20 dB HL for all the frequencies tested (Figure).

The average pure-tone thresholds for the right ear were 9.2 dB HL (SD 5.6) and 7.1 dB HL (SD 4.3) for solvent-exposed and non-exposed subjects, respectively. The average pure-tone thresholds for the left ear were 10.1 dB HL (SD 5.6) and 8.4 dB HL (SD 4.1) for solvent-exposed and non-exposed subjects, respectively. Significant differences between groups were observed for the right ear hearing thresholds (t = 2.0; p = 0.042). None of the subjects from either group exhibited a hearing impairment according to the WHO definition. However, five solvent-exposed subjects (10.4%) presented with an abnormal average equal to or above 26 dB HL in at least one ear, as compared

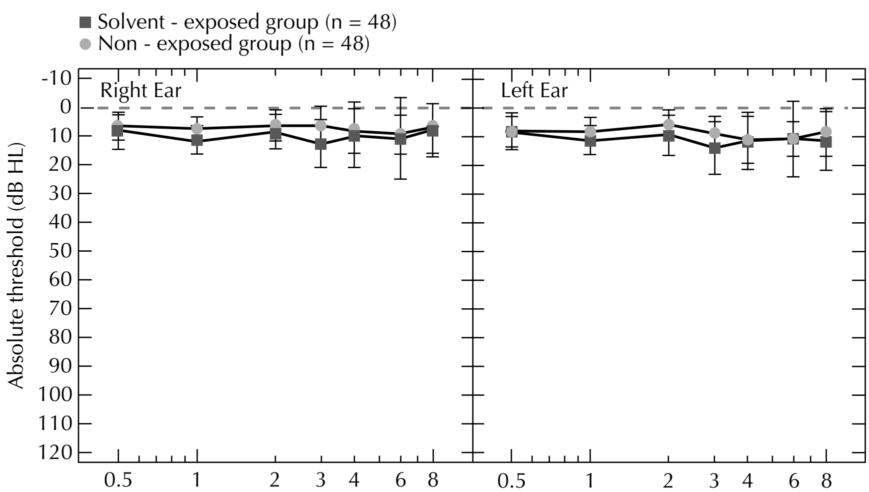

Figure. Mean right and left ear pure-tone thresholds and standard deviations for both groups.

Table 1. Hearing functions according to the ICF with the corresponding hearing disability factors of the AIADH.

Hearing functions (according to the ICF)	Factor structure of the AIADH or basic hearing disabilities
Speech discrimination (b 2304)	Intelligibility in quiet [items 8, 11, 12, 14, 20] Intelligibility in noise [items 1, 7, 13, 19, 25]
Sound discrimination (b 2301)	Distinction of sounds [items 4, 5, 6, 17,23, 24, 26, 29]
Sound detection (b 2300)	Detection of sounds [items 2, 10, 16, 22, 28]
Sound localization (b 2302) / sound lateralization (b 2303)	Auditory localization [items 3, 9, 15, 21, 27]
Excluded items	18, 30

ICF: International Classification of Functioning, Disability and Health
AIADH: Amsterdam Inventory for Auditory Disability and Handicap
( ) denotes ICF code
[ ] denotes items of the AIADH/-AIADH, Spanish version

with two non-exposed control subjects (4.1%) when average pure-tone thresholds for the high frequencies were explored. This difference in the proportion of subjects with hearing impairment between groups was not statistically significant ($\alpha^2 = 0.61$, $p = 0.43$).

Solvent-exposed subjects presented worse results than non-exposed subjects for all the RGD subtests (Table 2). Significant differences between solvent-exposed and non-exposed subjects were found for RGD 1,000 Hz ($p < 0.01$), RGD 4,000 Hz ($p < 0.01$) and RGD clicks ($p < 0.05$) subtests, when age was included as a covariate. Age was not significantly associated ($p > 0.05$) with either of the RGD subtest results.

Solvent-exposed subjects presented worse results than non-exposed subjects for the overall score of the AIADH questionnaire and for each of the four factors representing the four hearing functions proposed by WHO (sound detection, sound discrimination, speech discrimination and sound localization/lateralization) (Table 3). Solvent-exposed subjects presented significantly worse scores than control-group subjects for speech discrimination ($p < 0.05$), sound detection ($p < 0.01$) and sound localization/lateralization ($p < 0.05$), as well as for the overall score of the questionnaire ($p < 0.05$). No significant differences were observed between groups for the factor representing sound discrimination ($p > 0.05$). Age was not significantly associated ($p > 0.05$) with any of the factors of the questionnaire or with the overall score.

Significant slight negative correlations were observed between the overall score of the AIADH and the RGD clicks subtest score (P = -0.24, p = 0.01) and the overall score of the AIADH and the binaural average pure-tone threshold (P = -0.21, p = 0.03). No significant correlations were found between RGD clicks subtest score and binaural average pure-tone threshold (P = 0.17, p = 0.09).

DISCUSSION

Both groups of subjects presented grand mean hearing thresholds within normal ranges (≥ 20 dB HL). None of the subjects from either group presented a hearing impairment according to the WHO definition. Solvent-exposed subjects showed significantly worse hearing thresholds (average among 500, 1,000, 2,000 and 4,000 Hz) than control group subjects, for the right ear. When the average pure-tone threshold for the high frequencies (3,000, 4,000, 6,000 and 8,000 Hz) was calculated, 10.0% of solvent-exposed subjects showed abnormal audiograms as compared with 4.0% of non-exposed control subjects. This difference was not statistically significant. This is only partially in agreement with previous studies,[10,25] which found a higher prevalence of hearing loss in solvent-exposed workers than that found in this study.

Solvent-exposed subjects exhibited significantly worse results for the RGD test than non-exposed control subjects. These results are in agreement with previous studies which have indicated that solvent exposure is associated with central auditory dysfunction,[10,23] even in persons exposed to solvents who present normal

Table 2. Adjusted mean values for Random Gap Detection subtest scores, in milliseconds.

RGD subtest	Mean and (SE)		ANCOVA (F, p)
	Solvent-exposed	Non-exposed	
500 Hz (ms)	14.1 (1.6)	11.1 (1.7)	F = 1.5, p = 0.2
1,000 Hz (ms)	12.3 (1.4)	9.7 (1.5)	F = 7.4, p = 0.008
2,000 Hz (ms)	15.6 (1.7)	11.1 (1.7)	F = 3.4, p = 0.06
4,000 Hz (ms)	15.3 (1.3)	9.2 (1.4)	F = 9.9, p = 0.002
Clicks (ms)	10.5 (1.0)	6.9 (1.1)	F = 5.8, p = 0.018

RGD: Random Gap Detection; ANCOVA: Analyses of covariance; SE: Standard error

Table 3. Adjusted mean values for the Amsterdam Inventory for Auditory Disability and Handicap, Spanish version, for solvent-exposed and non-exposed subjects.

Amsterdam	Mean and (SE)		ANCOVA (F, p-value)
	Solvent-exposed	Non-exposed	
Sound detection (maximum score: 20)	18.2 (0.2)	19.1 (0.2)	F = 7.7, p = 0.007
Sound discrimination (maximum score: 32)	29.1 (0.3)	29.9 (0.3)	F = 3.6, p = 0.06
Speech discrimination (maximum score: 40)	33.9 (0.5)	35.7 (0.5)	F = 4.5, p = 0.03
Sound lateralization/localization (maximum score: 20)	17.8 (0.2)	18.7 (0.2)	F = 4.7, p = 0.03
Overall (maximum score: 120)	105.5 (1.2)	109.4 (1.2)	F = 4.6, p = 0.03

SE: Standard error; ANCOVA: Analyses of covariance hearing thresholds.[8] The two groups of subjects differed in laboratory tasks exploring the peripheral (hearing thresholds as measured by pure-tone audiometry) and central (temporal resolution as measured by the RGD test) auditory system. Solvent exposure may have adversely affected the peripheral and central auditory system in this study, as it has been previously suggested that the effects of solvents are due to a combination of oto-and neuro-toxicity.[20]

Solvent-exposed subjects reported poorer hearing performance in daily-life activities than non-exposed subjects. When the AIADH was analyzed according to the specific items associated with the four hearing functions categorized by WHO[28] (2001), solvent-exposed subjects reported poorer listening performance than non-exposed subjects for all the hearing functions, with the exception of sound discrimination. Subjects exposed to solvents reported poorer listening performance for sound detection (peripheral auditory function), speech discrimination (central auditory function) and sound localization/lateralization (central auditory function). The overall score of the AIADH was significantly correlated with the score for the clicks subtest of the RGD (central auditory function, temporal resolution) and with the average binaural hearing level (peripheral auditory function). Both correlations were negative, meaning that worse results (smaller numbers) for the AIADH were associated with worse (increased) results for pure-tone audiometry and RGD. No significant correlations were observed between the RGD clicks subtest and the binaural average of pure-tone thresholds. This indicates that both procedures selected to evaluate the peripheral and central auditory function did indeed evaluate different aspects of the auditory system. Despite both procedures evaluating different aspects of the auditory system, the AIADH was significantly correlated with both of them. The listening difficulties that solvent-exposed subjects may encounter in daily life may well be related to the adverse effects of solvents on both the peripheral and central auditory system.

One of the limitations of the present study was the lack of detailed information on personal solvent exposure. Environmental airborne solvent concentrations were obtained from available records of both factories from the past five years and workers were exposed to solvents over 13.5 years on average. Based on the available solvent exposure data, workers were not exposed to levels above the Chilean legislation or even above the National Institute for Occupational Safety and Health (NIOSH) recommendations of safety levels. Despite the low level of solvent exposure, solvent-exposed workers reported poorer listening performance for daily-life activities than non-exposed subjects. This was correlated with reduced measures of peripheral and central auditory system function. It is not possible to determine whether the levels of solvent exposure were higher in previous years. It is likely that workers had a higher occupational solvent exposure in the past due to previous, less strict local regulations in Chile. Therefore, based on the results of this study, it is not possible to suggest safe levels of solvent exposure for the auditory system. Future longitudinal studies with a comprehensive characterization of current and past levels of solvent exposure should be conducted to understand what levels of solvent exposure are safe for the auditory system.

The oto-and neuro-toxicity induced by solvents may adversely affect an individual's performance in listening activities such as sound localization, speech discrimination in quiet and in noise and sound detection, even in the absence of hearing loss as measured by conventional pure-tone audiometry. This effect is observed in a cohort of subjects exposed to a mixture of solvents for 13 years. The differences between solvent-exposed and non-exposed subjects may become more pronounced at older ages when the adverse effects of solvents on the auditory system interact with peripheral and central auditory changes related to aging, which should be explored in further studies.

The adverse effect of solvents on the auditory system can be screened with the use of self-report questionnaires exploring all aspects of audition (i.e., sound detection, sound discrimination, speech discrimination and sound localization/lateralization). The AIADH appears to be a useful tool for such purposes. Hearing conservation programs may consider the use of self-report questionnaires in conjunction with conventional hearing testing to determine whether solvent exposure is inducing an adverse effect on the auditory system and, subsequently, on the worker's listening performance in daily-life activities. Caution should be taken, as the results between conventional hearing testing and self-report questionnaires may not correlate well. This is especially true in the case of central auditory dysfunction associated with solvent exposure, where pure-tone audiometry can be within normal ranges and listening difficulties may still be reported.

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