· 环境与职业卫生 ·

某汽车制造企业不同车间噪声作业工人听力损失影响因素分析

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摘要:目的　分析某汽车制造企业中不同车间噪声作业工人听力损失的影响因素,提出相应的防护建议。**方法**　采用分层整群抽样,现场问卷调查收集研究对象基本情况、个人史、职业史及暴露情况,体检获得其听力结果。将研究对象按不同车间分为四组,即冲压车间、总装车间、涂装车间和焊装车间;按听力分组分为听力正常组及听力损失组。对符合纳入及排除标准的噪声作业工人的 1 411 人按不同车间及听力分组分析各暴露特征与听力损失的关系。**结果**　研究对象听力损失检出率 20.13%(284/1 411),总装车间听力损失检出率最高(25.00%),不同车间听力损失检出率差异有统计学意义($P<0.05$)。四个车间的噪声暴露声级、接噪工龄差异均有统计学意义($P<0.05$);噪声联合有机溶剂暴露的的听力损失检出率最高(34.55%),明显高于噪声联合粉尘(21.69%)、噪声联合其他因素(20.00%)及单独噪声(15.47%),各组间差异有统计学意义($P<0.01$)。总装及焊装车间以噪声联合有机溶剂暴露组的听力损失检出率最高,二个车间的各不同暴露组别间的差异有统计学意义($P<0.05$)。Logistic 回归显示:噪声联合有机溶剂及噪声联合粉尘暴露的工人发生听力损失的风险分别是单独噪声暴露的 2.67 倍($P<0.01$)及 1.43 倍($P<0.05$)。**结论**　汽车制造企业噪声联合有机溶剂及噪声联合粉尘暴露是作业工人听力损失的主要影响因素,总装车间听力损失检出率最高,应加强工作场所的噪声治理及健康防护,落实职业健康监护工作。

关键词:噪声;听力损失;汽车制造企业;作业工人;车间
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Analysis of factors influencing hearing loss in workers engaged in noise operations in different workshops of a certain automobile manufacturing enterprise

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Abstract: Objective　To analyze the influencing factors of hearing loss among workers in different workshop noise operations in a certain automobile manufacturing enterprise, and propose corresponding protective suggestions. **Methods**　A stratified cluster sampling method was employed, and on-site questionnaire surveys were conducted to collect basic information, personal history, occupational history, and exposure status of the study subjects. Physical examinations were performed to obtain their hearing results. The study subjects were divided into four groups based on different workshops: the stamping workshop, the assembly workshop, the painting workshop, and the welding workshop. They were also categorized into two groups based on hearing: the normal hearing group and the hearing loss group. The relationship between various exposure characteristics and hearing loss was analyzed for 1 411 noise-exposed workers who met the inclusion and exclusion criteria, categorized by different workshops and hearing groups. **Results**　The detection rate of hearing loss in the research subjects was 20.13% (284/1 411), with the highest detection rate in the assembly workshop (25.00%). There was a statistically significant difference in the detection rate of hearing loss among different workshops ($P<0.05$). The differences in noise exposure levels and noise exposure duration among the four workshops were statistically significant ($P<0.05$); The detection rate of hearing loss in noise combined with organic solvent exposure was the highest (34.55%), significantly higher than that

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in noise combined with dust (21.69%), noise combined with other factors (20.00%), and noise alone (15.47%), with statistically significant differences between the groups ($P<0.01$). The detection rate of hearing loss in the noise combined with organic solvent exposure group was the highest in the final assembly and welding workshops, and the differences between different exposure groups in the two workshops were statistically significant ($P<0.05$). Logistic regression showed that workers exposed to noise combined with organic solvents and noise combined with dust had 2.67 times ($P<0.01$) and 1.43 times ($P<0.05$) higher risk of hearing loss, respectively, compared to those exposed to noise alone. **Conclusion** The exposure of noise combined with organic solvents and noise combined with dust in automobile manufacturing enterprises is the main influencing factor of hearing loss among workers. The detection rate of hearing loss in the final assembly workshop is the highest. Therefore, it is necessary to strengthen noise control and health protection in the workplace, and implement occupational health monitoring.

Keywords: Noise; Hearing loss; Automobile manufacturing enterprises; Workers; Workshop

2020 年,我国工业企业噪声作业工人听力损失检出率达 26.88%,估计有 900 万以上噪声作业工人患有听力损失[1]。我国职业性噪声聋是仅次于尘肺的第二大法定职业病[2-3],由噪声直接或间接所致的疾病(如缺血性心脏病、烦躁、失眠和儿童认知功能障碍等)负担也逐渐加重[4]。此外,噪声性听力损失是一种可以预防的疾病[5-6]。汽车制造企业的生产工艺流程较为复杂,按照不同的工艺流程归类主要分为冲压车间、总装车间、涂装车间和焊装车间。研究显示,冲压、总装、涂装和焊装车间的噪声超标率高于其他生产工艺车间,尤其以冲压和焊装车间的噪声超标率最为严重[7-9],冲压和钻孔是噪声危害的重点岗位[10]。因此,对汽车制造企业中不同车间的噪声作业工人的听力状况的特征进行描述和分析,可对噪声性听力损失的防制工作提供参考。

1 对象与方法

1.1 对象 选择广州市某汽车制造企业中参加 2020 年度在岗职业健康检查的 2 608 人噪声作业工人作为研究对象。纳入标准:(1)男性、汉族工人;(2)接触噪声工龄≥1 年;(3)年龄18 ~45岁;(4)工作场所噪声接触水平:8 h 连续等效声级(LAeq,8 h)≥80 dB(A);(5)下班后不经常接触噪声。排除标准:(1)耳部疾病史、家族性耳聋遗传史、爆震史、头部外伤史等既往病史者;(2)纯音听阈测试结果显示为传导性耳聋者;(3)暴露于噪声联合多种(3 种及以上)危险因素者。本研究经广州市第十二人民医院(广州市职业病防治院)医学伦理委员会批准(审批号:2019065),研究对象均知情同意。

1.2 方法

1.2.1 问卷调查 所有受检工人需完成现场问卷调查,由经过统一培训的调查员进行现场监督和指导,并嘱咐其逐项填写。内容包括一般人口学资料、职业史、个人史、既往史、现患史和家族史等。对工龄的定义:接噪工龄分为 <5 年、5 ~10 年和 >10 年;职业史中佩戴防护用具的定义:佩戴频率分为从不佩戴、偶尔佩戴(1 ~2 次/周)、经常佩戴(3 ~5 次/周)和几乎每次都佩戴;个人史中下班后接触噪声(如交通噪声、生活噪声等)分为几乎不接触、偶尔接触、经常接触。

1.2.2 分组 将在健康档案中获取的资料按不同车间分为四组,即冲压车间、总装车间、涂装车间和焊装车间,各车间进行整群抽样。现场问卷调查 1 838 人,剔除问卷不完整的 105 人,调查率为 94.28%。符合纳入及排除标准的噪声作业工人共有 1 411 人进入分析。

1.2.3 听力损失判定标准 对所有受检工人进行纯音听阈测试,受检工人在受检前需脱离噪声作业环境 48 h 以上,使用采用 Madsen itera 听力计(丹麦麦迪逊公司)测试其双耳 500、1 000、2 000、3 000、4 000 及 6 000 Hz 频段纯音气导听阈。测试结果按照 GBZ49 -2014《职业性噪声聋诊断标准》[11]进行年龄和性别修正,排除其他疾病后,将单纯双耳任一频率纯音气导听阈值 >25 dB 判定为听力损失,设为听力损失组,其余为听力正常组[9]。

1.2.4 工作场所职业病危害因素的检测 噪声定期检测方法及判定标准依据为 GBZ/T189.8 -2007《工作场所物理因素测量第 8 部分 噪声》[12]和 GBZ 2.2 -2007《工作场所有害因素职业接触限值 第 2 部分:物理因素》[13],生产性噪声的职业接触限值见表 1。其他职业病危害因素定期检测方法及判定标准依据 GBZ159 -2004《工作场所空气中有害物质监测的采样规范》[14]、GBZ2.1 -2019《工作场所有害因素职业接触限值 第 1 部分:化学有害因素》[15]、和 GBZ2.2 -2007《工作场所有害因素职业接触限值 第 2 部分:物理因素》[13]。根据该企业 2020 年的《工作场所职业病危害因素检测报告》,职业病危害因素暴露分为噪声、噪声联合粉尘、噪声联合有机溶剂、噪声联合其他因素四类。粉尘指无机粉尘,包含金属粉尘及电焊烟尘;有机溶剂指甲苯、二甲苯、乙苯、乙酸丁酯、丁醇、甲醇;其他因素指紫外线、手传振动。

表 1　工作场所噪声职业接触限值

Table 1　Occupational exposure limits for workplace noise

接触时间	接触限值[dB(A)]	备注
5 d/w, =8 h/d	85	非稳态噪声计算 8 小时等效声级($_{LEX,8h}$)
5 d/w, ≠8 h/d	85	计算 8 小时等效声级($L_{EX,8h}$)
≠5 d/w	85	计算 40 小时等效声级($_{LEX,W}$)

1.3　统计学处理　录入后并进行一致性检验用 EpiData 3.1 软件,采用 SPSS 24.0 软件进行统计分析,用中位数与第 25、75 分位数[$M(P_{25},P_{75})$]对非正态数据进行统计描述,多组中心分布采用非参数分析进行差异性分析;计数资料的构成比采用卡方检验,当出现理论频数 <1 时采用 Fisher 确切概率法;将单因素分析具有统计学差异的因素使用 ENTER 法纳入多因素非条件 logistic 回归模型分析以矫正混杂偏倚。双侧检验,检验水准 $\alpha=0.05$。

2　结　果

2.1　基本情况　1 411 名的男性工人中位年龄 24.00(22.00,26.00)岁,中位接噪工龄 4.00(3.50,6.00)年,每天中位工接触噪声小时 8.00(8.00,8.00)小时,每周中位工作天数 5.00(5.00,5.00)天,中位噪声接触 LAeq,8h 为 84.20(82.9,86.30)dB(A)。

2.2　不同车间噪声接触强度、接噪工龄、听力损失和佩戴防护用具情况　冲压车间、总装车间、涂装车间和焊装车间各层人数分别占 10.06%、19.84%、9.71% 和 60.38%。各车间中噪声接触工人每天工作小时($H=4.57$、$P=0.207$)和每周工作天数($H=2.59$、$P=0.459$)无统计学差异。其中涂装车间噪声强度最高,中位噪声接触 LAeq,8h 为 86.20(83.40,88.80)dB(A),冲压车间噪声强度最低,中位噪声接触 LAeq,8h 为 83.10(82.40,85.25)dB(A),不同车间噪声暴露声级差异有统计学意义($H=95.99$,$P<0.001$);总装车间的接噪工龄最长,中位接噪工龄为 5.00(3.50,6.50)年,不同车间接噪工龄差异有统计学意义($H=10.27$,$P<0.001$);研究对象听力损失检出率 20.13%(284/1 411),总装车间听力损失检出率最高(25.00%),不同车间听力损失检出率差异有统计学意义($\chi^2=8.91$,$P=0.031$),详见表 2。

问卷调查结果显示,噪声接触工人在工作场所能够自觉经常佩戴或几乎每次都佩戴防护用具达 91.92%(1 297/1 411),不同车间佩戴防护用具差异无统计学意义($\chi^2=5.53$,$P=0.786$),详见表 3。

表 2　各车间接噪强度、接噪工龄及听力损失检出情况比较

Table 2　Comparison of noise intensity, noise pickup age and hearing loss detection among vehicles

车间	人数	接噪强度[dB(A)]	接噪工龄(年)	听力损失[n(%)]
冲压	142	83.10(82.40,85.25)	4.00(3.50,6.00)	32(22.54)
总装	280	84.60(83.40,89.60)	5.00(3.50,6.50)	70(25.00)
涂装	137	86.20(83.40,88.80)	4.00(3.50,6.50)	32(23.36)
焊装	852	83.55(82.60,85.60)	4.00(3.50,6.00)	150(17.61)
H 值或 χ^2 值		95.99[a]	10.27[a]	8.91[b]
P 值		0.000	0.016	0.031

注:a 表示 H 检验,b 表示 χ^2 检验。

表 3　各车间佩戴防护用具情况比较[n(%)]

Table 3　Comparison of wearing protective gear in each workshop[n(%)]

车间	人数	佩戴防护用具情况			
		从不佩戴	偶尔佩戴	经常佩戴	几乎每次戴
冲压	142	2(1.41)	10(7.04)	24(16.90)	106(74.65)
总装	280	8(2.86)	10(3.57)	43(15.36)	219(78.21)
涂装	137	2(1.46)	9(6.57)	25(18.25)	101(73.73)
焊装	852	23(2.70)	50(5.87)	146(17.14)	633(74.30)
χ^2 值			5.530		
P 值			0.786		

2.3　不同暴露特征听力损失检出情况　噪声联合有机溶剂暴露的听力损失检出率最高(34.55%),明显高于噪声联合粉尘(21.69%)、噪声联合其他因素(20.00%)、单独噪声(15.47%),各组间差异有统计学意义($\chi^2=14.15$,$P=0.003$)。详见表 4。

表 4　不同暴露特征听力损失情况比较

Table 4　Comparison of hearing loss by exposure characteristics

项目	人数	听力损失[n(%)]	χ^2 值	P 值
接噪工龄(年)			1.05	0.592
<5	806	155(19.23)		

（续表）

项目	人数	听力损失[n(%)]	χ^2 值	P 值
5～10	571	121(21.19)		
＞10	34	8(23.53)		
$L_{Aeq,8\ h}$			0.17	0.917
＜85	850	174(20.47)		
85～90	426	83(19.48)		
＞90	135	27(20.00)		
职业病危害因素暴露			14.15	0.003
噪声	433	67(15.47)		
噪声联合粉尘	793	172(21.69)		
噪声联合有机溶剂	55	19(34.55)		
噪声联合其他因素	130	26(20.00)		
防护用品使用			1.66	0.646
从不佩戴	35	9(25.71)		
偶尔佩戴(1～2 次/周)	79	16(20.25)		
经常佩戴(3～5 次/周)	238	53(22.27)		
几乎每次都佩戴	1 059	206(19.45)		

2.4　不同车间不同职业病危害因素暴露与听力损失检出情况　总装车间以噪声联合有机溶剂暴露的听力损失检出率最高(52.94%)，明显高于噪声联合其他因素(28.57%)、噪声(25.35%)、噪声联合粉尘(21.34%)，各组间差异有统计学意义(χ^2 = 8.44，P = 0.038)。焊装以噪声联合有机溶剂暴露的听力损失检出率最高(23.33%)，明显高于噪声联合粉尘(20.83%)、噪声联合其他因素(16.90%)、噪声(12.20%)，各组间差异有统计学意义(χ^2 = 9.91，P = 0.019)。听力损失检出率在冲压和涂装车间中不同职业病危害因素暴露的分组间无统计学差异(P ＞ 0.05)。详见表 5。

表 5　不同车间不同职业病危害因素暴露与听力损失关系比较

Table 5　Comparison of the relationship between different workshop exposure factors and hearing loss

车间	职业病危害因素暴露	人数	听力损失[n(%)]	χ^2 值	P 值
冲压	噪声	33	7(21.21)	1.79	0.618
	噪声联合粉尘	87	19(21.84)		
	噪声联合有机溶剂	4	2(50.00)		
	噪声联合其他因素	18	4(22.22)		
总装	噪声	71	18(25.35)	8.44	0.038
	噪声联合粉尘	164	35(21.34)		
	噪声联合有机溶剂	17	9(52.94)		
	噪声联合其他因素	28	8(28.57)		
涂装	噪声	34	6(17.65)	1.64	0.651
	噪声联合粉尘	86	23(26.74)		
	噪声联合有机溶剂	4	1(25.00)		
	噪声联合其他因素	13	2(15.38)		
焊装	噪声	295	36(12.20)	9.91	0.019
	噪声联合粉尘	456	95(20.83)		
	噪声联合有机溶剂	30	7(23.33)		
	噪声联合其他因素	71	12(16.90)		

2.5　多因素 logistic 回归分析　将听力损失作为因变量，单因素分析中有统计学差异的影响因素(接噪强度、接噪工龄、工作车间、职业病危害因素暴露)作为自变量进行二分类多因素 logistic 回归分析。结果显示，噪声联合有机溶剂及噪声联合粉尘暴露的工人发生听力损失的风险分别是单独噪声暴露的 2.67 倍(95% CI = 1.438～4.969，P = 0.002)及 1.43 倍(95% CI = 1.438～4.969，P = 0.025)，详见表 6。

表 6　听力损失相关影响因素的多因素 logistic 回归分析

Table 6　Multifactorial Logistic Regression Analysis of Hearing Loss Related Influential Factors

变量	β 值	SE	Wald 值	P 值	OR(95% CI)值
接噪强度	-0.01	0.02	0.06	0.801	0.995(0.955,1.036)
接噪工龄	0.04	0.03	1.36	0.244	1.039(0.974,1.107)
工作车间			6.70	0.082	
冲压车间					
总装车间	0.12	0.25	0.23	0.629	1.129(0.690,1.846)
涂装车间	0.05	0.29	0.03	0.855	1.054(0.598,1.860)
焊装车间	-0.28	0.22	1.53	0.216	0.760(0.492,1.174)
职业病危害因素暴露			11.11	0.011	
噪声					
噪声联合粉尘	0.36	0.16	5.00	0.025	1.432(1.045,1.962)
噪声联合有机溶剂	0.98	0.32	9.66	0.002	2.673(1.438,4.969)
噪声联合其他因素	0.26	0.26	0.97	0.325	1.290(0.777,2.142)

注：因变量赋值：听力正常 = 0，听力异常 = 1；自变量赋值：工作车间：冲压 = 1，总装 = 2，涂装 = 3，焊装 = 4；职业病危害因素暴露：噪声 = 1，噪声联合粉尘 = 2，噪声联合有机溶剂 = 3，噪声联合其他因素 = 4. 纳入、排除标准分别为 0.05、0.10。

3　讨　论

汽车制造业随着对汽车的需求量日益增长，成为了一个日益重要的行业，我国是全球最大的汽车市场及最大的汽车生产国[16]。在汽车制造业中众多的职业危害因素中，噪声是超标最为严重的一种[17]，其防

护依然是当前职业卫生工作中的重点和难点。

本次研究显示，该企业的听力损失检出率为 20.13%，低于李燕茹等[18]报道的广州某汽车制造企业的听力异常检出率为 34.47% 的结果和谢春姣等[19]报道的噪声作业工人听力损失检出率为 34.40% 的结果。本研究发现在各个汽车生产车间中，总装车间听力损失检出率最高(25.00%)，不同车间听力损失检出率差异有统计学意义($P < 0.05$)。现场检测报告显示，总装车间超标原因主要来源于使用呱生风板、电动葫芦、电池枪等工具紧固、拧紧工具作业时产生振动及噪声、敲打、金属部件的碰撞，且各车间的设备布局比较密集，易导致周边噪声作业岗位高强度噪声声场叠加。提示着该汽车制造企业仍需逐步革新设备，实现自动化，人机分离，并为作业人员配备合格的防护耳罩，并监督其正确佩戴。

随着新能源汽车的上市，汽车制造业蓬勃发展，新兴工艺、设备和化学品的使用使得职业病危害因素显得更加具有多样性和复杂性[20]，工作场所中的职业病危害因素几乎不可避免[21]，各车间中噪声、化学毒物以及粉尘等多种职业病危害因素并存[18]。近年来，人们越来越关注影响噪声对听力危害的联合作用因素，有毒有害物质如粉尘(包括电焊烟尘等)和有机溶剂(包括苯和苯系物等)也逐渐成为研究的热点[22]。汽车制造企业工作场所中，噪声联合其他职业有害因素会加速噪声性听力损失发病，以高温、振动、电焊烟尘和有机溶剂较为常见[22]。

蒲立力等[23]的研究发现，甲苯、二甲苯暴露为噪声作业人员高频听力损失的危险因素($P < 0.05$)。Choi 等[24]的研究显示，噪声和有机溶剂联合接触组工人在 2、3 和 4 kHz 频段的平均值是单纯噪声接触组的 2.15 倍。曾瑞坤等[25]的研究发现有机溶剂混合物与噪声联合暴露会引起作业工人听力损失。侯强等[26]的研究发现，含锰电焊作业产生的化学有害因素可能与噪声在引起噪声性听力损伤方面存在联合作用。本次研究发现，噪声联合有机溶剂暴露的的听力损失检出率最高(34.55%)，明显高于噪声联合粉尘(21.69%)、噪声联合其他因素(20.00%)及单独噪声(15.47%)，各组间差异有统计学意义($P < 0.01$)。进一步研究发现，总装及焊装车间以噪声联合有机溶剂暴露组的听力损失检出率最高，二个车间的各不同暴露组别间的差异有统计学意义($P < 0.05$)。Logistic 回归显示：噪声联合有机溶剂及噪声联合粉尘暴露的工人发生听力损失的风险分别是单独噪声暴露的 2.67 倍($P < 0.01$)及 1.43 倍($P < 0.05$)。本次研究与相关研究一致[23-26]，提示总装及焊装车间可能存在其他有害物质联合噪声暴露损失听力，应重点应关注总装及焊装车间的有机溶剂的使用。

综上所述，该企业总装车间的听力损失检出率比较高，应加强对总装车间的噪声防护管理。同时，噪声联合有机溶剂及噪声联合粉尘暴露对听力损失的影响可能更大，总装及焊装车间使用的有机溶剂等对听力损失的研究也需要进一步的探索。

但本次研究存在以下不足(1)属于横断面研究，研究对象年龄偏小，代表性不足，且可能低估了真实听力损失患病水平，因而在未来需要建立大型队列研究进一步验证听力损失的相关危险因素。(2)本研究仅纳入男性工人，研究结果不能外推至女性接噪工人。(3)未考虑累积噪声暴露量(CNE)对听力损失的影响，仅用某时点的接噪强度和接噪工龄代替累积噪声暴露量和累积噪声接触时间进行分析，无法全面准确地评估听力损失与噪声接触的剂量-效应关系。

利益冲突声明　本研究不存在任何利益冲突

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