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Evaluation of Long-Term Respiratory Effects of Exposure to Welding Fumes

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Abstract

Welding fumes are known to cause respiratory health problems. We aimed to evaluate the long-term respiratory effects of exposure to welding fumes. Inception cohorts of welding, plumbing, and heating apprentices were prospectively contacted 7-17 years post-apprenticeship. Questionnaires, as well as spirometry and non-specific bronchial hyperresponsiveness (NSBHR) tests were repeatedly administered. A long-term evaluation was done in 71 former apprentices at the Hôpital du Sacré-Cœur de Montréal between 2013 and 2017. Post-apprenticeship exposure to welding fumes and gasses was evaluated using three methods: self-report, expert assessment and the asthma-specific job exposure matrix. The incidence of wheezing and excessive lung function decline, given continued post-apprenticeship exposure to welding fumes, was estimated using Cox regression. Incident wheezing was found in 18.8% of subjects, and excessive lung function decline was observed in 12.7% of subjects. All three exposure assessment methods consistently showed that subjects with continued, post-apprenticeship exposure to welding fumes or gasses had a lower risk of developing wheezing symptoms or excessive decline in lung function, although none of the associations were significant. In conclusion, continued post-apprenticeship exposure to welding fumes does not seem to increase the risk of developing long-term respiratory outcomes.

Keywords: apprentices, lung function, occupational, welding

Evaluasi Dampak Jangka Panjang Pajanan Asap dan Gas Pengelasan Terhadap Kesehatan Pernapasan

Abstrak

Asap dan gas pengelasan *(welding fumes and gasses)* diketahui dapat menyebabkan masalah pernapasan. Penelitian ini dilakukan untuk mengevaluasi efek pernapasan jangka panjang dari pajanan asap dan gas pengelasan. Mantan peserta sekolah kejuruan pengelasan secara prospektif dihubungi 7-17 tahun pasca-pendidikan. Subjek penelitian melengkapi kuesioner, uji spirometri dan uji bronkus non-spesifik. Evaluasi jangka panjang dilakukan pada 71 subjek di Hôpital du Sacré-Cœur de Montréal antara tahun 2013 dan 2017. Pajanan asap dan gas pengelasan pasca-pendidikan dievaluasi menggunakan tiga metode: laporan oleh pekerja, penilaian oleh ahli dan penggunaan matriks pajanan di tempat kerja pekerjaan khusus. Hubungan antara pajanan asap dan gas pengelasan dengan insidens mengi dan penurunan fungsi paru-paru berlebihan dievaluasi menggunakan regresi Cox. Insidens mengi ditemukan pada 18,8% subjek, dan penurunan fungsi paru berlebihan diamati pada 12,7% subjek. Ketiga metode penilaian pajanan secara konsisten menunjukkan bahwa subjek dengan pajanan asap dan gas pengelasan pasca-pendidikan memiliki risiko lebih rendah terkena gejala mengi atau penurunan fungsi paru-paru yang berlebihan, meskipun tidak ada hubungan yang bermakna. Sebagai kesimpulan, pajanan asap dan gas pengelasan jangka panjang tampaknya tidak meningkatkan risiko penurunan fungsi pernapasan.

Kata kunci: fungsi paru, pekerjaan, asap dan gas pengelasan

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Introduction

Work-related asthma includes work-exacerbated asthma (pre-existing asthma or concurrent asthma that is worsened by workplace exposures) and OA (asthma induced by agents in the workplace). On the basis of general population-based studies, 17.6% of adult-onset asthma is attributable to occupational exposure.[1] More than 400 different agents in the workplace have been identified as causing OA,[2] including high-molecular-weight, HMW, (mostly proteins) and low-molecular-weight, LMW, (mostly chemical) agents. For the former, the most common causal agents include flour and laboratory animal allergens, to which bakers and laboratory animal workers are respectively exposed to. For the latter, the most common etiologic agents include cleaning products, isocyanates and wood dust, to which health care workers, cleaners, car painters, and carpenters might be exposed to.[3] OA is associated with work impairment [4,5] impaired quality of life, and psychological distress.[6,7]

The international multicenter population-based Respiratory Health in Northern Europe study showed that adult-onset rhinitis and asthma were consistently higher among welders across population samples from Northern Europe.[8] Our previous study, comprising an apprentice cohort of welders in the province of Quebec that were followed up for 18 months, demonstrated exposure to welding fumes to be associated with respiratory symptoms and pulmonary function changes.[9] A substantially increased number of subjects with percent predicted forced expiratory volume in one second (%pFEV1) <80% and non-specific bronchial hyperresponsiveness (NSBHR) were observed.[9]

The current study aimed to: (1) estimate post-apprenticeship incidence of wheezing and excessive decline in lung function; (2) assess the association between post-apprenticeship, continued exposure to welding fumes and gasses and these outcomes; and (3) assess the association between work productivity and activity impairment with lower respiratory symptoms suggestive of OA.

Methods

Design and Sample

To answer our study objectives, we re-contacted the inception cohort of 286 welders and 44 plumbing and heating apprentices, 7-17 years post-apprenticeship. Between September 2013 and April 2017, 90 of 330 (27.2%) eligible subjects participated in a long-term follow-up.

Standardized respiratory, work history, as well as work impairment and activity impairment (WPAI) for specific health problems questionnaires, were administered at follow-up. In addition, participants underwent a lung function test using spirometry and a methacholine challenge test to assess NSBHR.[9,10] The study was approved by the Hôpital du Sacré-Cœur de Montréal research ethics committee (CER 2012-801).

Measurements

Two primary outcomes were evaluated. First, the incidence of wheezing (absent at the end of apprenticeship) was considered present if subjects reported wheezing in the past 12 months. Second, an excessive decline in lung function from the end of apprenticeship to the end of follow-up was defined as a decrease in $\%pFEV_1 \geq 15\%$ based on Knudson equation.[11] Our secondary outcome was WPAI assessed using questionnaires.[12] Absenteeism (work time missed), presenteeism (reduced on-the-job effectiveness), work productivity loss (overall work impairment: absenteeism plus presenteeism), and activity impairment in the past seven days were calculated.

Demographic and clinical determinants of incident wheezing and excessive respiratory decline at follow up were explored. NSBHR was defined as the provocative concentration of methacholine causing a 20% decrease in FEV1 (PC20) ≤8 mg/ml. We also evaluated changes in lung function and bronchial responsiveness to methacholine during apprenticeship and post-apprenticeship. An increase in bronchial hyper-responsiveness during apprenticeship was defined as (1) having a 3.2-fold decrease in PC_{20} from baseline to the end of apprenticeship, or (2) a change at the end of apprenticeship to a PC_{20} of 16 mg/ml or less in subjects with an initial PC_{20} of greater than 32 mg/ml.[13]

Exposure Assessment

Three methods were used to assess continued, post-apprenticeship exposure to welding fumes and gasses: self-report, expert assessment, and asthma-specific job exposure matrix (JEM). Subjects were asked to report the type of jobs, tasks assigned, and any welding activities performed at their workplace. Since self-reports are prone to recall bias, an occupational hygienist used information reported by participants on their job(s), task(s) and the company(ies) in which they worked to classify their exposures. For each job reported, a three-point score (0, 1 and 2) was used by the hygienist to assess exposure. A zero score indicated no exposure to welding fumes; 1 indicated possible exposure (i.e., working in a welding environment); and 2 implied probable exposure (i.e., having a job with welding task). Subjects were categorized as being continuously exposed if any of the jobs were coded as one or two and held for one year or longer. Finally, the International Standard Classification of Occupations (ISCO-88) codes assigned by the hygienist to post-apprenticeship held-jobs were subsequently linked with the JEM. Subjects were considered to have had "current exposure" if they were in occupations involving exposure to welding fumes (i.e., welders) or irritant gases or fumes (i.e., plumbers) for at least one year. Unexposed subjects or those who had been exposed for less than a year post-apprenticeship in their current job, composed the reference group. A similar approach was previously used by our group to evaluate post-apprenticeship outcomes in other cohorts.[13,14]

We included 71 subjects who had questionnaire responses and respiratory function test results at the end of the apprenticeship. Kappa coefficients and percentage of the agreement were computed to evaluate agreement between self-report, expert assessment and JEM exposure categories on estimates of continued exposure to welding fumes and gasses post-apprenticeship.[15] For estimating the incidence of wheezing, we excluded subjects with missing wheezing information (n=8) or those who reported wheezing at the end of apprenticeship (n=6). Cox regression was used to estimate hazards ratios (HRs) and corresponding 95% confidence intervals (CIs) for the associations between each of characteristics at the end of apprenticeship and continued exposure to welding fumes with the incidence of primary outcomes. WPAI outcomes were expressed as impairment percentages, with higher numbers indicating greater impairment and less productivity, i.e., worse outcome.[12] Data analyses were performed using IBM SPSS for Windows version 24.0 (SPSS, Inc., Chicago, IL).

Results

Participants who did not participate were similar to those who participated regarding their characteristics (age, smoking status, BMI, wheezing and NSBHR) at the end of apprenticeship (results not shown).

The incidence of wheezing was 21% (12 of 57 subjects). An excessive decline in %pFEV$_1$ was found in 9 out of 71 (12.7%) subjects with respiratory function test results.

Subjects reported having held up to a maximum of 12 jobs when they were contacted after 17 years. Based on expert assessment and JEM, almost all (69 of 71 subjects) have ever had a job with exposure to welding fumes or gasses. Based on self-report, 45 (78.9%) subjects have ever been exposed. As for the current job, according to expert-assessment, 37 of 71 (52.1%) subjects have ever been exposed to welding fumes for at least one year. The number exposed to welding fumes were slightly lower (49.2%) based on asthma-specific JEM, and much lower (38.0%) based on self-report. The percent agreement was 86.0% between expert assessment and JEM (kappa coefficient (k) 0.719, $p<0.001$), and 85.9% ($k=0.721$, $p<0.001$) between expert assessment and self-report and 74.7% ($k=0.491$, $p<0.001$) between self-report and JEM.

Table 1 shows the distribution of demographic, clinical, and exposure characteristics by the incidence of wheezing during the long-term follow-up. As

Table 1. Distribution of Demographic, Clinical, and Exposure Characteristics By the Incidence Of Wheezing During Long-Term Follow-Up

	Incidence of Wheezing		HR (95% CI)
	No N=47	Yes N=13	
Characteristics at the end of apprenticeship			
Mean age (SD), years	26.1 (8.1)	23.9 (6.5)	0.98 (0.88-1.08)
Male sex	38 (84.4)	9 (75.0)	0.74 (0.19-2.76)
Current smoking	16 (35.6)	5 (41.7)	1.31 (0.41-4.13)
Body mass index (mean, SD)	25.2 (3.8)	22.6 (3.1)	0.85 (0.71-1.01)
Overweight (body mass index ≥ 25 kg/m^2)	20 (44.4)	3 (25.0)	0.59 (0.16-2.18)
Predicted FEV1, mean (SD)	97.7 (14.6)	98.4 (22.5)	1.01 (0.98-1.04)
Non-specific bronchial hyperresponsiveness ($PC_{20} \leq 8$ mg/mL)	5 (11.1)	5 (41.7)	2.22 (0.69-7.04)
Tightness	5 (11.1)	3 (25.0)	1.63 (0.44-6.09)
Cough	1 (2.2)	1 (8.3)	2.17 (0.27-17.24)
Changes during apprenticeship			
Excessive decline in percentage of FEV1	6 (13.3)	1 (8.3)	0.59 (0.08-4.63)
Increase in bronchial responsiveness	6 (13.3)	3 (25.0)	1.16 (0.31-4.33)
Post-apprenticeship exposure to welding fumes			
Self-reports	17 (37.8)	4 (33.3)	0.52 (0.16-1.73)
Expert assessment	24 (53.3)	6 (50.0)	0.95 (0.31-2.97)
Asthma-specific job exposure matrix	23 (51.1)	7 (58.3)	1.48 (0.47-4.68)
Work duration (years)			
Self-reports (median, IQR)	1.7 (0, 8.2)	1.4 (0, 8.7)	0.97 (0.87-1.08)
Expert assessment (median, IQR)	0 (0, 7.5)	0 (0, 8.0)	0.94 (0.83-1.06)
Asthma-specific job exposure matrix (median, IQR)	1.2 (0, 7.5)	4.6 (0, 8.8)	0.94 (0.83-1.06)

Data are in n (%) unless otherwise noted.

CI: confidence interval; FEV1: forced expiratory volume in 1 second; HR: hazard ratio; IQR: interquartile range; PC20: methacholine concentration that causes a 20% fall in FEV1; SD: standard deviation.

displayed in Table 1, NSBHR, cough or chest tightness, or being a smoker at the end of apprenticeship were associated with a higher risk of developing wheezing (HRs ranged between 1.3 and 2.2). However, no statistically significant associations were observed. The observed associations between current welding exposure and wheezing were inconsistent across the exposure assessment type (HRs ranged from 0.5 to 1.5), with none reaching statistical significance.

Table 2 shows a non-significant increased risk of excessive lung function decline in subjects who were overweight and in those who reported wheezing, chest-tightness or cough at the end of the apprenticeship. All three exposure assessment methods consistently showed that subjects who were currently exposed to welding fumes had a lower incidence of excessive lung function decline. The univariate HRs ranged from 0.4 to 0.8.

Only two subjects reported a WPAI due to respiratory symptoms one week prior to the interview. One of them is an overweight male welder aged 40-years old, who also reported to be a smoker. The other is a male welder with persistent wheezing since the end of apprenticeship but had normal lung function. He was overweight at follow-up.

Table 2. Distribution of Demographic, Clinical, and Exposure Characteristics By Excessive Respiratory Decline During Long-Term Follow-Up

	Excessive respiratory decline		HR
	No N=62	Yes N=9	95% CI
Characteristics at the end of apprenticeship			
Mean age (SD), years	25.3 (7.8)	23.9 (6.5)	1.01 (0.89-1.14)
Male sex	52 (83.9)	7 (77.8)	0.54 (0.10-2.78)
Current smoking	27 (45.8)	3 (33.3)	0.65 (0.16-2.63)
Body mass index (mean, SD)	24.4 (3.9)	24.4 (3.7)	1.04 (0.82-1.30)
Overweight (body mass index ≥ 25 kg/m^2)	18 (33.3)	4 (57.1)	3.09 (0.67-14.24)
Predicted FEV1, mean (SD)	96.5 (15.6)	113.1 (14.3)	1.04 (0.99-1.09)
Non-specific bronchial hyperresponsiveness ($PC_{20} \leq 8$ mg/mL)	12 (19.4)	1 (11.1)	0.59 (0.07-4.98)
Wheezing	6 (10.9)	1 (11.1)	1.28 (0.15-10.68)
Tightness	3 (8.3)	1 (20.0)	1.54 (0.16-14.97)
Cough	2 (3.6)	2 (22.2)	3.08 (0.61-15.65
Changes during apprenticeship			
Excessive decline in pFEV1	9 (14.5)	1 (11.1)	0.75 (0.09-6.49)
Increase in bronchial responsiveness	9 (14.8)	1 (11.1)	0.49 (0.06-4.02)
Current exposure to welding fumes			
Self-reported	24 (38.7)	3 (33.3)	0.42 (0.11-1.70)
Expert-assessment	33 (53.2)	4 (44.4)	0.65 (0.17-2.43)
Asthma-specific JEM	31 (50.0)	4 (44.4)	0.83 (0.22-3.11)
Work duration (years)			
Self-reported (median, IQR)	0 (0, 6.2)	0 (0, 8.8)	0.94 (0.82-1.08)
Expert-assessment (median, IQR)	1.4 (0, 7.0)	0 (0, 8.8)	0.97 (0.85-1.09)
Asthma-specific JEM (median, IQR)	1.0 (0, 6.9)	0 (0, 8.8)	0.94 (0.82-1.08)

Data are in n (%) unless otherwise noted.
CI: confidence interval; FEV1: forced expiratory volume in 1 second; HR: hazard ratio; IQR: interquartile range; PC20: methacholine concentration that causes a 20% fall in FEV1; SD: standard deviation

Discussion

Our findings suggest that subjects with continued, post-apprenticeship exposure to welding fumes or gasses had a lower risk of developing wheezing or an excessive decline in lung function. The observed associations were consistent across all exposure assessment methods. A healthy worker effect (HWE) might explain our findings. This is in accordance with a study in a New Zealand urban population where cumulative exposure to gases/fumes was associated with a higher %pFEV_1, suggesting a likely consequence of an HWE.[16]

We observed a higher incidence of wheezing in subjects who were smokers, reported chest tightness or a cough or had NSBHR at the end of the apprenticeship. We also found a higher incidence of excessive lung function decline in subjects who were overweight or reported lower respiratory symptoms at the end of the apprenticeship. Although associations did not reach statistical significance, this is concomitant with a previous study by Wang and colleagues who found that being overweight was related to a lower level and steeper slope of decline in pulmonary function.[17]

Two symptomatic welders reported mild to moderate WPAI in the past week. None reported missing work or reducing hours of work due to respiratory symptoms, but reported work impairment by 10-20% and activity impairment by 20-40%. The WPAI questionnaires are designed to inquire about impairment in work productivity and activities up to 7 days.[12] Therefore, our findings might not reflect the potential long-term impact of occupational exposure on work productivity and activity.

There are potential limitations to this study. First, the sample size was small. As such, for current exposure-outcome associations, our reference group consisted of unexposed subjects or those who were exposed for less than a year post-apprenticeship. This could have resulted in underestimating the observed associations. Second, we had a low participation rate (27.2%). Non-response in observational epidemiologic studies may bias association estimates because of potential selection bias.[18] In our study, however, the characteristics at the end of the apprenticeship of subjects who participated in our long-term follow-up did not significantly differ from those who did not participate.

Conclusion

Post-apprenticeship exposure to welding fumes and gases was not associated with an increased risk of developing long-term respiratory outcomes. An inverse association was found between post-apprenticeship exposure to welding fumes and long-term respiratory disease development.

Conflict of Interest

The authors have no conflicts of interest associated with the material presented in this paper.

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