Annals of Work Exposures and Health, 2021, Vol. 65, No. 9, 1029–1039
doi: 10.1093/annweh/wxab034
Advance Access publication 4 June 2021
Original Article

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Wood Dust Exposure Levels and Respiratory Symptoms 6 Years Apart: An Observational Intervention Study Within the Danish Furniture Industry

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Submitted 12 January 2020; revised 11 April 2021; editorial decision 15 April 2021; revised version accepted 23 April 2021.

Abstract

Objectives: Occupational exposure to wood dust can cause respiratory diseases, but few studies have evaluated the impact of declining exposure on health outcome. This study aimed to investigate whether a decline in wood dust exposure between two cross sectional studies performed in 1997–1998 and 2003–2004 was related to the prevalences of respiratory symptoms among woodworkers in a well-defined geographical area.

Methods: Two thousand and thirty-two woodworkers from 54 plants in study 1 and 1889 woodworkers from 52 plants in study 2 returned a questionnaire on respiratory diseases and symptoms, employment and smoking habits. Current individual wood dust exposure level was assessed from 2 study specific job exposure matrix's based on task, factory size and personal passive dust measurements (2217 in study 1 and 1355 in study 2).

Results: The median (range) of inhalable dust was 1.0 mg/m^3 (0.2–9.8), 0.6 mg/m^3 (0.1–4.6) in study 1 and study 2, respectively. In study 2, the prevalence's of self-reported asthma was higher and the prevalence's of respiratory symptoms were lower compared to study 1. In adjusted logistic regression analyses using GEE methodology to account for clustering, dust exposure level could explain the differences in prevalence of coughing, chronic bronchitis and nasal symptoms between study 1 and study 2, while no effect was found for asthma.

Conclusions: A 40% decline in wood dust exposure in a 6 year period may serve as an explanation for the decline in most respiratory symptoms, but do not seems to impact the prevalence of self-reported asthma.

What's Important About This Paper?

Wood dust exposure in the furniture industry is associated to increased risk of respiratory symptoms and diseases. However, there is a lack of studies evaluating the impact of decreases in exposure to wood dust on respiratory health. In a time span of 6 years there were declines in the prevalence of ever wheezing (2.4%), coughing (4.9%), chronic bronchitis (2%) and nasal symptoms (6%), which was mainly explained by a 40% decrease in wood dust exposure, when comparing two cross-sectional cohorts of furniture workers. Decrease in wood dust exposure may result in fewer workers experiencing respiratory symptoms.

Keywords: cross sectional studies; epidemiology; respiratory symptoms; asthma; occupation; furniture industry; wood dust exposure; intervention

Introduction

Occupational exposure to wood dust is common and has been estimated to effect approximately 3.6 million (2% of the working population) in the European Union of which 700.000 are exposed in the furniture industry.

Wood dust is a known risk factor for cancer in the nasal cavity and is classified as a human carcinogen (International Agency for Research on Cancer 1995, 2012). Furthermore wood dust exposure can be a risk factor for asthma. A meta-analysis of 19 population based studies showed a pooled relative risk for asthma of 1.5 (95% CI 1.2–1.9) among wood dust exposed workers (Perez-Rios *et al*., 2010). A systematic review from 2016 including industry based studies confirmed an overall risk of asthma among wood dust exposed workers, Relative Risk in meta-analysis 1.5 (95% CI 1.3–1.9) (Wiggans *et al*., 2016).

Quite a few studies, mainly cross sectional, have associated wood dust exposure to increased risk of symptoms from the nose (Åhman *et al*., 1995;Alwis *et al*., 1999b; Rongo *et al*., 2002) and the eyes (Norrish *et al*., 1992; Alwis *et al*., 1999b; Osman *et al*., 2009), but also to coughing (Åhman *et al*., 1995; Alwis *et al*., 1999a; Schlünssen *et al*., 2002; Jacobsen *et al*., 2009). Chronic impairment in lung function including COPD has been suggested (Shamssain, 1992; Mandryk *et al*., 1999; Osman *et al*., 2009), also from follow-up studies (Glindmeyer *et al*., 2008; Jacobsen *et al*., 2008; Bolund *et al*., 2018), but with inconsistent results. Positive exposure-response relations between wood dust exposure and respiratory impairment are indicated in quite a few studies (Shamssain, 1992; Halpin *et al*., 1994; Bohadana *et al*., 2000; Douwes *et al*., 2001; Schlünssen *et al*., 2002; Schlünssen *et al*., 2004a; Douwes *et al*., 2006; Jacobsen *et al*., 2008; Jacobsen *et al*., 2009; Bolund *et al*., 2018).

As far as we are aware only one study has evaluated the impact of interventions in the wood industry on respiratory symptoms (Stocks *et al*., 2013). They evaluated national level interventions with inconclusive results. Two intervention studies assessed reduction in dust exposure, but they did not relate exposure to health outcomes (Lazovich *et al*., 2002; Douwes *et al*., 2017).

In a 6-year follow-up study in the Danish furniture industry, we investigated the impact of wood dust exposure and respiratory diseases. At follow-up, a new cross-sectional study was initiated in order to investigate the trend in wood dust exposure and respiratory impairment in the furniture industry in a well-defined geographical area exposed mainly to softwood (pine and spruce) and wooden boards (particle boards, medium density fibreboards) (Jacobsen *et al*., 2008; Jacobsen *et al*., 2009). The overall inhalable geometric mean (geometric standard deviation) wood concentration decreased from 0.9 (2.1) mg/m^3 to 0.6 (1.6) mg/m^3 (Schlünssen *et al*., 2008) reflecting a 7% annual decrease, which is in line with findings from other countries (Teschke *et al*., 1999; Galea *et al*., 2009).

The purpose of this study was to investigate whether this decline in wood dust concentration had any impact on the prevalence of respiratory symptoms among furniture workers.

Material and Methods

Study population

The study populations were identified in two cross sectional studies at wooden furniture factories performed 6 years apart. The baseline study (hereafter study 1) took place during the winter of 1997/1998 as described elsewhere (Schlünssen *et al*., 2002). In brief, 86 factories situated in Viborg County with more than 4 employees were identified. All factories with more than 20 employees were invited, and 45 of 48 accepted. Additionally a random sample of 9 out of 38 factories with 5–20 employees was included, in total 54 factories. The second study (hereafter study 2) took place in the same area 6 years later during the winter of 2003/2004. 52 out of 59 factories with more than 4 employees identified accepted to participate, of which 38 had participated in the baseline study as well. The study population comprised workers employed in the woodworking, assembly and stock departments of these factories. A total of 2032 (response 85%) and 1.886 (response 82%) participated in the first and second study respectively, of whom 779 participated in both studies.

All participants gave informed consent, and the protocol has been approved by the Ethics Committee for Viborg County, Denmark.

Health outcomes

A modified British Medical Research Council Questionnaire (1965), including key ECRHS questions on asthma (Burney *et al.*, 1994), with additional questions on allergy, coughing, asthma, rhinitis, nasal symptoms, conjunctivitis, smoking, and occupational history was distributed at both studies (Schlünssen *et al.*, 2002).

'Current asthma' was defined as current self-reported asthma, 'ever-asthma' as current or former self-reported asthma. 'Ever wheeze' was present when reporting wheezing without a cold. 'Daily coughing' was defined as usual coughing during the day, and chronic bronchitis as expectoration on most days during ≥3 months for >2 years consecutively according to UK Medical Research Council Guidelines (1965). Nasal symptoms were defined as answering yes to ≥ 1 nasal symptom (rhinorrhoea, nasal itching, nasal congestion or sneezing) during the last year; and rhinitis as an affirmative answer ≥2 nasal symptoms, ≥2 days a week during the last year. Similarly, conjunctivitis was defined as yes to ≥2 eye symptoms (itching, stinging, running or swelling) at ≥2 days a week during the last year. Being atopic was defined as ever hay fever.

'Smokers' were current smokers or ex-smokers for <2 years prior to the study. Smoking were further quantified as <20 and ≥20 cigarettes pr. day. Pack years were calculated as cigarettes per day divided by 20 and multiplied by years of smoking. To include other types of tobacco, one cigarette was defined as equivalent to 0.56 cheroot or 1.25 g pipe tobacco (Kjærgaard *et al.*, 1986).

Exposure Assessment

Personal dust sampling was carried out at all factories in study 1, and on a stratified random sample of factories in study 2 with passive dust monitors described earlier (Vinzents, 1996; Schlünssen *et al.*, 2001). In summary the method is based on measuring light extinction before and after sampling on transparent sticky foils, reported as dust covered foil area and converted to equivalent inhalable dust by linear regression models based on earlier and actual calibration measurements (Vinzents, 1996; Schlünssen *et al.*, 2008). Internal Job Exposure Matrices (JEM) based on factory size and task were constructed in study 1 (12 groups, 2.217 measurements, 1.581 individuals) and study 2 (7 groups, 1.355 measurements, 1.044 individuals) (Schlünssen *et al.*, 2004b; Jacobsen *et al.*, 2008). The groupings were based on random effect analyses, where grouping by task and factory size achieved the greatest contrast between the groups (Schlünssen *et al.*, 2004b).

Analysis

When data were normally distributed, mean ± SD is reported, otherwise the median (range) is shown. In further analyses, we used multiple logistic regressions with adjustment for potential confounders. In order to account for clustering caused by workers participating in both study 1 and study 2, and to obtain robust standard errors, we used GEE (generalized estimation equation) methodology using the Stata command cluster. In the fully adjusted model, we included current wood dust exposure level, sex, age, atopy, and smoking status. In a sub analysis, we repeated the analysis among workers participating in both studies.

Statistical analyses were performed in Stata 11 (Stata Corp., College Station, TX, USA).

Results

Demographics

In study 2 the participants were older, and a higher percentage were females compared to study 1 (Table 1). Workers who participated in both studies were per definition 6 years older in study 2 compared to study 1, while workers participating in only one of the studies had an average age difference of only 1.7 years. Workers who participated in both studies were older than those participating in just one study (data not shown).

There was slightly fever current smokers in study 2 compared to study 1, OR (95% CI) 0.89 (0.80–0.99), but smokers in study 2 tended to smoke more, OR (95% CI) for ≥ 20 cig/day, 1.19 (1.00–1.41). Furthermore, among smokers OR for ≥ 20 pack-years in study 2 vs. study 1 was 1.37 (95% CI 1.15–1.62) (data not shown). Workers participating in both studies had a similar

Table 1. Demographic characteristics of the population.

	Total population of wood workers			Sub-population participating in both studies		
	Study 1	Study 2	*P*	Study 1	Study 2	*P*
Subjects, *n*	2032	1886		779	779	
Males (%)	1664 (81.9)	1461 (77.5)	<0.01	652 (83.7)	652 (83.7)	1
Age, years AM (SD)	37.2 (11.3)	40.8 (11.2)	<0.01	38.3 (9.9)	44.3 (9.8)	<0.01
History of atopy[#] (%)	262 (13.5)	258 (13.9)	0.68	90 (12.1)	97 (12.7)	0.74
Missing	93	35		35	13	
Smokers[¶] n (%)	925 (47.6)	805 (44.9)	0.04	321 (43.1)	287 (38.5)	0.07
Missing	90	92		35	33	
Smoking Status						
Non-smoker, *n* (%)	1017 (52.4)	989 (55.1)	0.07	423 (56.9)	459 (61.5)	0.03
Smokers[¶] <20 cig/day	523 (26.9)	424 (23.6)		191 (25.7)	143 (19.2)	
Smokers[¶] ≥20 cig/ day	390 (20.1)	375 (20.9)		126 (16.9)	141 (18.9)	
Smoker[¶], unknown cig/day	12 (0.6)	6 (0.3)		4 (0.5)	3 (0.4)	
Missing	90	92		35	33	
Measured wood mg/m^3, median (range)	0.99 (0.17–9.78)	0.59 (0.10–4.65)	<0.01	0.96 (0.17–7.96)	0.57 (0.10–2.89)	<0.01
>1 mg/m^3 (%)	791 (49.1)	108 (11.5)	<0.01	301 (48.0)	40 (10.5)	<0.01
Missing	422	946		152	398	
JEM wood dust mg/m^3, median (range)	0.82 (0.37–1.61)	0.55 (0.28–0.91)	<0.01	1.04 (0.37–1.61)	0.55 (0.28–0.91)	<0.01
Missing	44	70		7	31	
Woodwork > 5 years (%)	1205 (60.0)	1300 (69.0)	<0.01	564 (73.1)	774 (99.4)	<0.01
Missing	23	2		7	0	
Main wood type last year						
Softwood	1127 (57.0)	851 (53.9)	0.07	376 (49.7)	322 (52.4)	0.32
Hardwood	222 (11.4)	70 (4.6)	<0.01	101 (13.4)	25 (4.1)	<0.01
Wood veneers & composite wood[α]	374 (19.3)	293 (19.9)	0.68	168 (22.6)	133 (22.5)	0.98
Mixed & other wood types	276 (14.1)	328 (21.5)	<0.01	123 (16.4)	124 (20.4)	0.05
Missing	77	359		27	172	

Data are presented as *n* (%) of valid cases unless otherwise stated.

[#] Positive atopic status: when yes to former or present hay fever.

[¶]Smokers are current smokers and ex-smokers, who stopped smoking less than two years prior to the study. Smoking (categorized into non-smokers, smokers <20 cig/day and ≥20 cig/day). Composite wood[α]: Plywood or MDF ± coating/veneer.

smoking profile compared to the total study population (Table 1).

Current wood dust exposure levels were around 40% lower in study 2 compared to study 1, both for the total population and for workers participating in both studies. Workers in study 2 in general had a higher seniority compared to study 1. Roughly, half of the study population(s) used softwood, 4–13% hardwood, 20% wood veneers & composite, and 14–20% other wood types.

Respiratory symptoms

Table 2 presents unadjusted prevalence's of respiratory symptoms for study 1 and study 2 for the total population, and for workers participating in both studies. More workers reported current asthma and ever asthma, and fewer workers reported symptoms (ever wheeze, daily coughing, symptoms of chronic bronchitis, nasal symptoms and conjunctivitis) in study 2 compared to study 1. For workers participating in both studies the picture was slightly different, i.e. symptoms of wheezing, chronic bronchitis and conjunctivitis was not reduced in study 2 compared to study 1. Analyses by sex, smoking and atopic status showed roughly similar results, but with a slight tendency for a stronger decline in respiratory symptoms for non-smokers, and non-atopic individuals (see supplementary Tables S1–S3 in online edition).

In Table 3 crude and adjusted logistic regression models for the association between study (study 1 reference) and self-reported asthma and respiratory

Table 2. Prevalence of self-reported respiratory symptoms at two cross-sectional studies 6 years apart.

	Total population of wood workers				Sub-population of wood workers participating in both studies			
	Study 1		Study 2		Study 1		Study 2	
	Subjects Included [missing]	Prevalence *N* (%)	Subjects Included [missing]	Prevalence *N* (%)	Subjects Included [missing]	Prevalence *N* (%)	Subjects Included [missing]	Prevalence *N* (%)
Current asthma	1987 [45]	77 (3.9)	1843 [43]	93 (5.1)	767 [12]	30 (3.9)	762 [17]	37 (4.9)
Ever asthma	1952 [80]	120 (6.2)	1822 [64]	149 (8.2)	759 [20]	44 (5.8)	753 [26]	52 (6.9)
Wheeze ever	1976 [56]	399 (20.2)	1845 [41]	328 (17.8)	758 [21]	130 (17.2)	761 [18]	131 (17.2)
Daily Coughing	1941 [91]	637 (32.8)	1820 [66]	507 (27.9)	750 (29]	219 (29.2)	748 [31]	197 (26.3)
Chronic bronchitis	1749 [283]	166 (9.5)	1663 [223]	125 (7.5)	676 [103]	55 (8.1)	694 [85]	63 (9.1)
Nasal symptoms	1959 [73]	956 (48.8)	1843 [43]	788 (42.8)	744 [35]	352 (47.3)	762 [17]	300 (39.4)
Conjunc-tivitis	1959 [73]	175 (8.9)	1836 [50]	134 (7.3)	757 [22]	55 (7.3)	763 [16]	58 (7.4)

Data are presented as *N* (%) of included subjects.

symptoms are presented. For *ever asthma* and *conjunctivitis* similar ORs for study were seen in the crude and adjusted models, respectively.

Compared to the unadjusted OR (1.32 (95% CI 1.00–1.73) for *current asthma* OR for study decreased slightly after adjusting for wood dust to 1.13 (95% CI 0.78–1.64).

For *ever wheeze*, *daily coughing*, chronic *bronchitis* and *nasal symptoms* the decreased OR for study in the unadjusted models were approaching OR 1 in the adjusted models, and this could mainly be ascribed to the adjustment for wood dust exposure (Table 3). Further adjusting for sex, smoking, age and atopy only slightly changed the wood dust only adjusted estimate. This is further illustrated in Fig. 1.

The above analyses were repeated for workers participating in both studies (see supplementary Table S4 in online edition). Similar directions of most results were found, but with more variability, and with no clear patterns for chronic bronchitis and ever wheeze.

In the fully adjusted logistic regression models smoking increased the odds for all respiratory outcomes, with ORs ranging from 1.37 for nasal symptoms to 15.3 for chronic bronchitis, Table 4.

An exposure response relation was seen between current wood dust exposure and *daily coughing* (trend test, p = 0.01), with OR 1.44 (95% CI 1.08–1.91) in the highest exposure tertile. No clear exposure –response patterns were seen for current wood dust exposure and *chronic bronchitis*, *nasal symptoms* and *conjunctivitis*.

Atopy was associated to all the reported outcomes with ORs ranging from 1.55 for daily coughing to 17.2 for nasal symptoms (Table 4). Chronic bronchitis was strongly associated to sex with OR 9.13 for males.

Further analyses including smoking as a dummy variable did not change the results, but confirmed the association between respiratory symptoms and smoking with OR between 1.13 and 14.22 (see supplementary table S5 in online edition). Due to interaction between sex and smoking for daily coughing and chronic bronchitis, respectively, a stronger relation to smoking was seen for females, *daily coughing* OR 4.58 (95% CI 3.20–6.56) and *chronic bronchitis* OR 14.22 (95% CI 3.32–60.9). Results were consistent for both smokers and non-smokers (see supplementary Table S6), and atopics and non-atopics (see supplementary Table S7). However, the decline in respiratory symptoms from study 1 to study 2 was only significant in the larger group of non-atopic workers.

We repeated the analyses using a) the JEM based wood dust level as a continuous variable (data not shown) and b) the measured wood dust for the

Table 3. Crude and adjusted associations between respiratory symptoms and study round in logistic regression models.

	Total population						
	Respiratory symptoms*						
	Current Asthma	Asthma Ever	Wheeze Ever	Daily Coughing	Chronic Bronchitis	Nasal Symptoms	Conjunctivitis
	N = 3830	*N* = 3774	*N* = 3821	*N* = 3761	*N* = 3412	*N* = 3802	*N* = 3795
OR crude	1.32	1.36	0.85	0.79	0.78	0.78	0.80
	(1.00–1.73)	(1.09–1.69)	(0.74–0.99)	(0.69–0.90)	(0.62–0.97)	(0.70–0.88)	(0.64–1.00)
OR adjusted	*N* = 3724	*N* = 3670	*N* = 3715	*N* = 3657	*N* = 3318	*N* = 3694	*N* = 3687
wood dust exposure+	1.13	1.24	0.94	0.93	1.01	0.86	0.82
	(0.78–1.64)	(0.91–1.69)	(0.76–1.17)	(0.77–1.12)	(0.75–1.36)	(0.73–1.02)	(0.60–1.11)
OR adjusted	*N* = 3652	*N* = 3602	*N* = 3648	*N* = 3589	*N* = 3268	*N* = 3619	*N* = 3612
Sex, smoking¶, age†	1.23	1.31	0.89	0.80	0.80	0.84	0.80
	(0.92–1.65)	(1.03–1.66)	(0.76–1.05)	(0.70–0.92)	(0.62–1.02)	(0.74–0.95)	(0.64–1.00)
OR adjusted atopy±	*N* = 3729	*N* = 3678	*N* = 3723	*N* = 3660	*N* = 3328	*N* = 3767	*N* = 3718
	1.36	1.36	0.85	0.80	0.79	0.78	0.80
	(1.02–1.81)	(1.08–1.72)	(0.73–0.98)	(0.70–0.92)	(0.63–1.00)	(0.68–0.88)	(0.64–1.01)
OR adjusted all#	*N* = 3464	*N* = 3420	*N* = 3465	*N* = 3405	*N* = 3104	*N* = 3491	*N* = 3446
	1.13	1.25	0.98	0.99	0.96	0.93	0.95
	(0.73–1.72)	(0.88–1.77)	(0.77–1.25)	(0.81–1.21)	(0.69–1.33)	(0.77–1.13)	(0.68–1.33)

* Reference study 1 in all models.
Variables in models: + JEM wood dust exposure (tertiles)
¶ Smoking (categorized to non-smokers, smokers <20 cig/day and ≥20 cig/day.
Smokers are current smokers and ex-smokers, who stopped smoking less than two years prior to the study.
† age (continuous).
± Positive atopic status, when yes to former or present hay fever
adjusted for wood dust, sex, smoking, age and atopy.

subpopulation with available measurements (supplementary Table S8) and these measurements dichotomized in measurements below and above 1 mg/m^3 (Supplementary Table S9). These analyses did not change the overall results. The dichotomized exposure analysis supported the main analysis, where exposure above 1 mg/m^3 was associated to all respiratory symptoms except *conjunctivitis, current-* and *ever asthma* with OR ranging from 1.27 for *daily coughing* to 1.50 for *chronic bronchitis* (supplementary Table S9).

Finally we took seniority in the wood industry into account. Including years of employment in the industry in the regression model barely changed the results (data not shown). A negative association between seniority and coughing was revealed. OR for workers who had been employed 2–8 years and >8 years respectively in the furniture industry was 0.87 (95% CI 0.70–1.08) and 0.77 (95% CI 0.62–0.97) compared to <2 years, trend test $p = 0.024$ (data not shown). Stratification by seniority (below and above 5 years of employment) revealed the same pattern for the two strata, but with a more pronounced decline in respiratory symptoms and rise in reported asthma from study 1 to study 2 among workers with less than 5 years of seniority, supplementary Table S10 and S11.

Discussion

To the authors knowledge this is the first study in the wood industry that investigates the relation between changes in wood dust exposure on the subsequent change in prevalence's of respiratory symptoms. This study compares 2 cross-sectional study populations within the same geographical area and industry 6 years apart and reports a decline in wood dust exposure, a decline in the prevalence's of self-reported lower and upper respiratory symptoms and a simultaneous rise in self-reported asthma. The decline in coughing, chronic bronchitis and nasal symptoms from study 1 to study 2 were mainly explained by differences in the wood dust exposure level, and dose-response relations was observed for coughing.

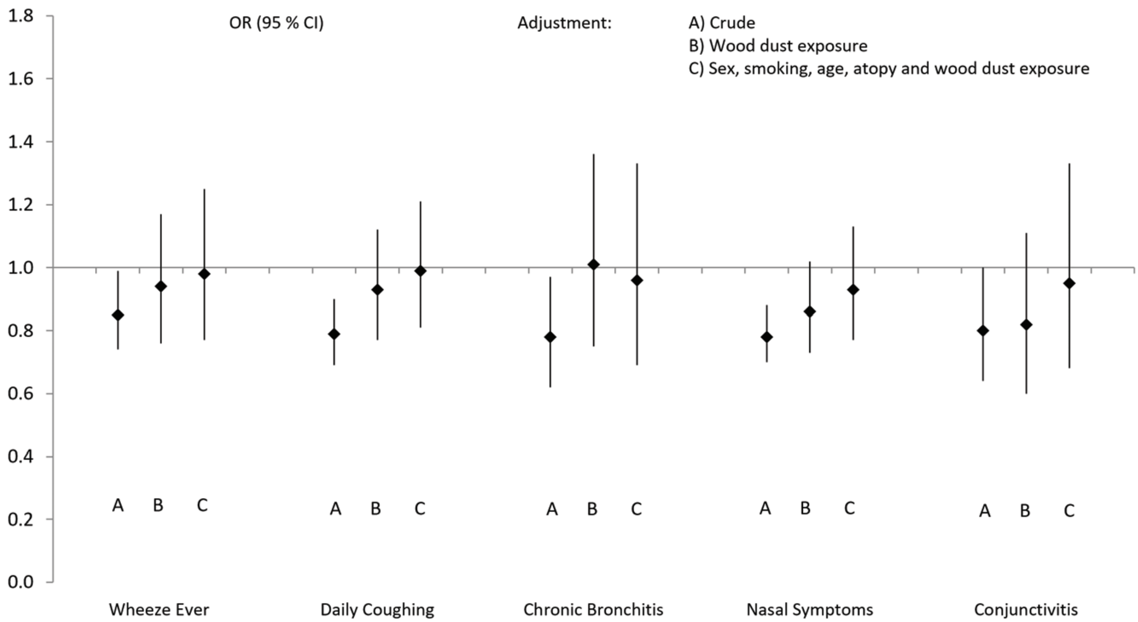

Figure 1. Association between respiratory symptoms and study in logistic regression models adjusted for potential confounders - displaying change in OR's for study depending on inclusion of wood dust exposure and additional confounders.

The revealed associations between wood dust exposure level and respiratory symptoms are in accordance with previous studies reviewed by e.g. Wiggans *et al* (2016) and Jacobsen *et al* (2010). In the dry wood industry exposure response relation between wood dust exposure and *coughing* has been revealed by Shamssain (1992) using duration of employment as a proxy of exposure to wood dust, by Åhman *et al* (1995) in a study of industrial art teachers comparing workers in 'good shop' with 'poor shops', and by our group in the follow-up of study 1 between baseline wood dust exposure and cumulative incidence of coughing among female workers (Jacobsen *et al.*, 2009). Significant positive association between *chronic bronchitis* and wood dust exposure has also been suggested in earlier studies (Åhman *et al.*, 1995; Alwis *et al.*, 1999a; Jacobsen *et al.*, 2009) with a positive exposure response relation for female workers in one study (Jacobsen *et al.*, 2009).

In this paper, we report a decline of 6 % (from 49% to 43%) in nasal symptom last year (rhinorrhea, nasal itching, blocked nose or sneezing) related to a decline in wood dust exposure.

The decline in nasal symptoms with decline in wood dust exposure is also in accordance with most studies on rhinitis, work-related rhinitis, nasal symptoms or work-related nasal symptoms, which have reported increased frequencies of symptoms with increasing exposure (Holness *et al.*, 1985; Norrish *et al.*, 1992; Pisaniello *et al.*, 1992; Shamssain, 1992; Åhman *et al.*, 1995; Talini *et al.*, 1998; Alwis *et al.*, 1999a; Bohadana *et al.*, 2000; Rongo *et al.*, 2002; Osman *et al.*, 2009) though a few studies haven't revealed this association (Goldsmith *et al.*, 1988; Schlünssen *et al.*, 2002). The prevalence of rhinitis is within the range of previous studies, which reported frequencies of 10–52 % among woodworkers compared to non-exposed controls or groups with lower exposure (Holness *et al.*, 1985; Pisaniello *et al.*, 1991; Talini *et al.*, 1998; Rongo *et al.*, 2002).

This study can be regarded as an 'observational intervention study' where the impact of reduced exposure to wood dust on respiratory outcomes is estimated. Previously intervention studies in the wood industry have focused on behavioural changes and the resulting wood dust exposure without focusing on symptoms (Lazovich *et al.*, 2002). The SWORD surveillance scheme on work-related respiratory disease in the UK reported an overall declining incidence of work-related asthma between 2001 and 2011, but they found no significant changes in respiratory diseases attributed to wood dust relative to other agents, that is the declining trends were keeping pace with the overall declining trend not supporting nor ruling out the possibility of an impact of interventions (Stocks *et al.*, 2013). An intervention study among young farmers in Denmark demonstrated reductions between 20 and 30% in personal exposure to inhalable dust through information

Table 4. Adjusted association between respiratory symptoms, study round, wood dust, age, sex, smoking and atopic status.

Independent variables	Respiratory Symptoms[#] Wheeze Ever N = 3465	Daily Coughing[†] N = 3405	Chronic Bronchitis[†] N = 3104	Nasal Symptoms N = 3491	Conjunctivitis N = 3446
Study[α]	0.98 (0.77–1.25)	0.99 (0.81–1.21)	0.96 (0.69–1.33)	0.93 (0.77–1.13)	0.95 (0.68–1.33)
Sex[β]	1.00 (0.79–1.29)	1.34 (0.97–1.86)	9.13 (2.22–37.5)	0.75 (0.61–0.91)	0.49 (0.36–0.66)
Smokers					
<20 cig. /day[¶]	2.60 (2.07–3.28)	3.96[a] (2.67–5.86)	15.31[c] (3.45–67.9)	1.37 (1.15–1.65)	1.10 (0.82–1.49)
>20 cig. /day[¶]	4.44 (3.52–5.59)	6.09[b] (3.70–10.0)	11.68[d] (2.36–57.8)	1.47 (1.21–1.79)	0.92 (0.65–1.31)
Wood dust mg/m[3+]					
0.64–0.76	0.98 (0.77–1.26)	1.27 (1.03–1.56)	1.51 (1.04–2.19)	1.22 (1.00–1.48)	1.23 (0.86–1.76)
0.77–1.61	1.13 (0.81–1.59)	1.44* (1.08–1.91)	1.47 (0.90–2.40)	1.22 (0.92–1.60)	1.37 (0.85–2.18)
Atopic[≠]	2.89 (2.27–3.68)	1.55 (1.24–1.93)	1.80 (1.30–2.51)	17.23 (12.3–24.1)	4.96 (3.77–6.53)

Data are presented as N, odd ratio (95% confidence interval).
[#] age (continuous variable) included in all models.
[α] reference study 1.
[β] reference females.
[¶] reference non-smokers. Smokers are current smokers and ex-smokers, who stopped smoking less than two years prior to the study.
[+] reference: 0.27–0.63 mg/m^3.
[≠] Positive atopic status, when yes to former or present hay fever.
[†] Negative interaction between male sex and smoking in the model.
[a, b,c,d] OR shown for female smokers; male smokers: [a] OR: 1.72 (1.38–2.15); [b] OR: 3.11 (2.52–3.85); [c] OR: 1.68 (1.15–2.44); [d] OR: 3.02 (2.18–4.18).
*Trend across tertiles of wood dust exposure p = 0.01.

provided to the farm owners regarding actual levels of exposure together with instructions on basic measures of prevention (Basinas *et al.*, 2016), but this type of intervention was yet to come within the wood industry.

Risks for asthma among wood dust exposed workers are well documented. A meta-analysis based on 19 population studies found a pooled relative risk of asthma of 1.53 (95% CI 1.25–1.87), but they could not confirm an exposure-response relation (Perez-Rios *et al.*, 2010). Wiggans *et al.* (2016) confirmed this results in a meta-analysis on industry based studies. We observed an increase in self-reported asthma during the study period. A general rise in asthma prevalence is well documented (Janson *et al.*, 2018), and might be due either to increased asthma prevalence caused by other factors than occupation, or alternatively to secular changes in diagnostic awareness and labelling of asthma (Sunyer *et al.*, 1999). The prevalence and changes in the asthma prevalence were however small compared to the prevalences of respiratory symptoms rendering our study with limited power to detect a possible change in asthma prevalence linked to wood dust exposure. One should also note that while respiratory symptoms as for instance coughing can be a symptom of asthma, coughing is a nonspecific symptom reflecting acute respiratory irritation as well as chronic lung disease.

Roughly 20% of the study participants used wood veneers & composite, and 14–20% other wood types. It is therefore possible that (a decline) in other substances but wood dust *per see* might contribute to our findings. Composite boards (e.g. medium density fibreboards (MDF) and chip board) may contain formaldehyde known to able to cause respiratory symptoms (Burton *et al.*, 2011; Thetkathuek *et al.*, 2016). We have earlier reported low levels of formaldehyde exposure in the study population with a median (range) of 0.05 (0.03–0.2) mg/m^3 using a worst-case measurement strategy on factories using MDF and chip board (Jacobsen *et al.*, 2009). Around 50% of the study population used soft wood, mostly pine wood, and terpenes emitting from pine wood is also known to able to cause respiratory symptoms as summarized in (Hagstrom *et al.*, 2012). We have earlier evaluated the terpene level in the current cohort and found AM (range) of monoterpene exposure at 17 pine factories to be 12 mg/m^3 (1.4–77 mg/m^3) (Hagstrom *et al.*, 2012), and well below the Danish occupational exposure limit of 25 ppm, which roughly corresponds to 150 mg/m^3 (The Danish Working Environment Authority, 2007). Taken together, we have no strong indications that other exposures but wood dust explains our findings.

This study was performed in a cross-sectional setting comparing two populations at different times. The response rates were high in both the studies, 85 % and 82 % respectively. As the study was performed in the same area and largely on the same factories, a total of 38 % of the participant in study 1 and 41 % in study 2 participated in both studies. Therefore, analyses were performed with adjustment for clustering in order to account for a possible dependency between workers participating in both studies. Adjustment for clustering resulted in decreased standard-errors and narrower confidence intervals in the analyses but did not change the ORs. For the group of workers participating in both studies the results were clearly attenuated compared to the total study population. An obvious explanation for this could be selection. We expect the proportion of workers staying in the wood industry is on average healthier, which was also observed in our follow-up study, where workers included outside the factories showed a higher prevalence of asthma symptoms and hay fever compared to workers invited at the factories (Jacobsen *et al.*, 2009). In line with that, woodworkers in study 2 had a higher seniority in the industry and a negative association between seniority in the wood industry and coughing was revealed, indicating a healthy worker effect with selection away from the wood industry for workers with symptoms. Also, the group of woodworkers with higher seniority had lower decline in respiratory symptoms from study 1 to study 2. This could tend to attenuate the effect of wood dust exposure on symptoms. However, including seniority in the wood industry in the analyses indicates this effect to be negligible.

In both study 1 and study 2 exposure to wood dust were based on JEM's estimated from a large number of personal dust measurements, work task and factory size. Information on individual work task was collected on the same day, as the factories were visited, but for the minority of workers who were absent, information on task was based on questionnaire information on main tasks during the last month. We repeated the analysis on the subgroup of workers with wood dust measurement and found similar results. Therefore, a possible recall bias is unlikely.

Not surprisingly there was a strong relation between respiratory symptoms and atopic disposition. However, as atopic status was defined as self-reported hay-fever and not based on golden standards of skin prick test or test for specific immunoglobulin E, analyses including the influence of atopic status may be underestimated due to possible non-differential misclassification of atopic status.

One could speculate whether the association between reduction in wood dust exposure and reduction in respiratory symptoms are a proxy of other simultaneous changes in the industry i.e. changes in the physical or psychological work environment. Dust reducing approaches i.e. encapsulation or larger degree of automation resulting in workers working at a greater distance from the processing might at the same time introduce changes that might influence the reporting of symptoms, but we are not able to explore this in the present study. The studies were performed in the same geographical area, and the study designs in study 1 and study 2 were similar with regards to inclusion of factories and subjects. In study 1, however only a random sample of small factories (<20 employees) were invited, whereas in study 2 invitations was given to all furniture factories with more than 4 employees in Viborg County which increased the percentage of subjects employed at small factories from 2% to 6%. As Viborg County compared with Denmark in general, was characterized by an excess of large factories and by factories using pinewood in production the results may underestimate the general dust level in the Danish Furniture Industry (Schlünssen *et al.*, 2001). However as approximately 80% of the Danish Furniture Industry workers are engaged at factories with more than 20 employees the result in general are assumed to be representative for the vast majority of the furniture industry workers.

In conclusion, the present study supports a decline in wood dust exposure in a 6-year period may serve as an explanation for the decline in respiratory symptoms. If this is true, reduction of wood dust exposure even in a low exposed population can reduce respiratory symptoms, and this calls for a continuous focus on evidence based dust reducing initiatives.

Supplementary Data

Supplementary data are available at *Annals of Work Exposures and Health* online.

Acknowledgments

The authors wish to thank Michael Væth for statistical assistance and Anders Mikkelsen, Nils Testrup Andersen and Eva Kristiansen for participation in the data collection. Also thanks to the workers and furniture factories in the former Viborg County for participation in the study.

Funding

Main funding contributors for the Wood study were the Danish Work Environment Foundation, the Danish Medical Research Council, the Danish Health Insurance Fund, the Danish Lung Association and Viborg County. The funding sources had no involvement in decisions made in regard to the study and publication.

Contributors

G.J. has contributed to idea and concept, data collection, analysis and interpretation of data and drafting of the article. I.S. has contributed to idea and concept and critical revision of manuscript for important intellectual content. T.S. has contributed to idea and concept, data interpretation and critical revision of manuscript for important intellectual content. V.S. has contributed to idea and concept, data collection and interpretation and critical revision of the manuscript for important intellectual content. All authors have approved the submitted article.

Conflict of interest

The authors declare no conflict of interest relating to the material presented in this Article. Its contents, including any opinions and/or conclusions expressed, are solely those of the authors.

Data availability

Documentation for how the analyses have been performed can be provided by contacting the corresponding author.

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