OPEN ACCESS

ORIGINAL ARTICLE

Cross-shift and longitudinal changes in FEV_1 among wood dust exposed workers

Gitte Højbjerg Jacobsen,[1,2] Vivi Schlünssen,[1] Inger Schaumburg,[3] Torben Sigsgaard[1]

[1]Department of Public Health, Section of Environmental and Occupational Medicine, Aarhus University, Aarhus, Denmark
[2]Department of Occupational Medicine, Herning Hospital, Herning, Denmark
[3]Neuro Centre, Aarhus University Hospital, Aarhus, Denmark

Correspondence to
Dr Gitte Højbjerg Jacobsen, Department of Occupational Medicine, Herning Hospital, Gl. Landevej 61, 7400 Herning, Denmark;
gitte.jacobsen@dadlnet.dk

Received 17 January 2012
Revised 23 July 2012
Accepted 26 August 2012
Published Online First 26 September 2012

ABSTRACT

Objectives Acute lung function (LF) changes might predict an accelerated decline in LF. In this study, we investigated the association between cross-shift and longitudinal changes in forced expiratory volume in 1 s (FEV_1) among woodworkers in a 6-year follow-up study.

Methods 817 woodworkers and 136 controls participated with cross-shift changes of FEV_1 at baseline and FEV_1 and forced vital capacity at follow-up. Height and weight were measured and questionnaire information on respiratory symptoms, employment and smoking habits was collected. Wood dust exposure was assessed from 3572 personal dust measurements at baseline and follow-up. Cumulative wood dust exposure was assessed by a study-specific job exposure matrix and exposure time.

Results The median (range) of inhalable dust at baseline and cumulative wood dust exposure was 1.0 (0.2–9.8) mg/m^3 and 3.8 (0–7.1) mg year/m^3, respectively. Mean (SD) for %ΔFEV_1/workday and ΔFEV_1/year was 0.2 (6.0)%, and −29.1 (41.8) ml. Linear regression models adjusting for smoking, age, height and weight change showed no association between cross-shift and annual change in FEV_1 among woodworkers or controls. Including different exposure estimates, atopy or cross-shift change dichotomised or as quartiles did not change the results.

Conclusions This study among workers exposed to low levels of wood dust does not support an association between acute LF changes and accelerated LF decline.

What this paper adds

- Studies have associated wood dust to both acute cross-shift changes and accelerated decline in lung function (LF).
- Furthermore, studies among workers exposed to organic dust have suggested cross-shift changes in lung forced expiratory volume in 1 s to be predictive of accelerated decline in LF.
- Cross-shift changes in LF do not predict an accelerated decline in LF.
- Cross-shift change in LF cannot be used to predict longitudinal changes in LF among woodworkers.

INTRODUCTION

Exposure to wood dust is common in the European Union, where approximately 3.6 million are occupationally exposed.[1] Occupational exposure to wood dust has long been associated with respiratory symptoms, including asthma, chronic bronchitis, bronchial hyper-reactivity,[2] cross-shift decline in forced expiratory volume in 1 s (FEV_1)[3–5] and decreased lung function (LF).[6–10] Most studies have been cross-sectional, and no studies have previously studied the effect of cross-shift changes in LF on longitudinal changes among workers exposed to dry wood dust.

An accelerated decline in LF when exposed to wood dust could theoretically be caused by repeated cross-shift declines in FEV_1 maintaining an increased level of airway responsiveness.[11]

If an accelerated decline in LF could be predicted from cross-shift changes this could be used to monitor the effect of changes in the work environment.

In this cohort, we have previously reported a dose–response relationship between wood dust exposure and cross-shift decline in FEV_1 among woodworkers, and for female workers a dose–response relationship between cumulative wood dust exposure and longitudinal decline in LF.[5 10]

An association between cross-shift decline in LF indices and subsequent decline in LF has been studied in other industries comprising grain workers,[12 13] wood trimmers,[14] textile workers[15–18] and swine confinement workers,[19] related to exposure to grain dust, cotton dust,[15–18] mold spores[14] and endotoxins.[18 19]

The aim of the present study was to investigate a possible relationship between acute cross-shift change in LF and accelerated decline in LF in a population of woodworkers and controls in order to elucidate whether cross-shift changes could predict chronic LF changes.

MATERIALS AND METHODS

Study population

The baseline study population was identified in a cross-sectional study performed between 1997 and 1998 which is described elsewhere.[20] In brief, 86 factories situated in Viborg County with more than four employees were identified. All factories with more than 20 employees were asked to participate (45 of 48 accepted), and additionally a random sample of factories with 5–20 employees (9 of 38) was drawn. A total of 54 factories participated in the study. The study population comprised dayshift workers employed in the woodworking departments, assembly departments and stock departments of these factories. Control workers were

To cite: Jacobsen GH, Schlünssen V, Schaumburg I, *et al*. *Occup Environ Med* 2013, **70**, 22–28.

selected from three factories in the same area (two producing refrigerators and one producing hearing aids) where only mechanical assembly was performed.

A total of 1.301 woodworkers and 215 controls returned a questionnaire and participated with valid cross-shift LF tests at baseline and were defined as the baseline population for follow-up. Or alternatively: A total of 1.301 woodworkers and 215 controls participated with a questionnaire and a valid cross-shift LF at baseline and were defined as the baseline population at follow-up. Follow-up took place from 2003 to 2005. Visits to 52 furniture factories (38 participated at baseline) and three control factories resulted initially in contact with 635 persons from the exposed group and 120 controls. The remaining subjects were contacted by letter and invited to a follow-up examination. In total, 817 woodworkers (63%) and 136 controls (63%) participated at follow-up. A flowchart of the study is shown in figure 1.

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

Exposure assessment

Personal dust samplings were carried out at baseline and follow-up with passive dust monitors described earlier.[21 22] 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.[21–23] In order to calculate cumulative wood dust exposure in the follow-up period, job exposure matrices based on factory size and task were constructed at baseline and at follow-up. The groupings were based on random effect analyses, where grouping by task and factory size achieved the greatest contrast between the groups.[5 24]

A modified British Medical Research Council questionnaire,[25] including key The European Community Respiratory Health Survey questions on asthma,[26] with additional questions on allergy, coughing, asthma, rhinitis, smoking and occupational history including work tasks was distributed at baseline and follow-up.[20]

Individual cumulative exposure was estimated from the exposure level at baseline for half the period (until 2001) and the exposure level at follow-up for the remaining period.

Smokers were defined as current smokers and ex-smokers, who stopped smoking less than 2 years prior to the baseline.

Measurements of LF

Pulmonary function testing was performed using a dry spirometer (Vitalograph, Buckingham, UK) according to European Respiratory Society guidelines for standardisation of spirometry.[27] The same spirometer was used for all measurements at baseline and follow-up. All measurements were conducted by the same research group of three individuals. FEV_1, forced vital capacity (FVC), height and weight were measured. At baseline 98.4% and at follow-up 99.7% was acceptable and included in the analyses. At baseline, preshift and cross-shift values were measured at the workplace, and 297 subjects had an additional LF at a later clinical examination at the hospital. At follow-up, preshift values were measured at factories and the remaining part of the cohort, not working at one of the factories, were invited to a LF test. A total of 69 subjects had an additional LF test at a later clinical examination at the hospital.

The highest FVC and FEV_1 at baseline were used to calculate percentage of pred. (predicted) values at baseline. As a reference, we used the Danish standards for age 30 years and above supplied by the Danish Society of Lung Physicians,[28] and a Danish reference material among healthy, non-smoking farming students[29] for the group between 15 and 29 years.

Percentage cross-shift change in FEV_1 at baseline was calculated as FEV_1 postshift minus FEV_1 preshift divided by FEV_1 preshift.

During follow-up, change in FEV_1 was calculated as $FEV_{1\ max}$ at follow-up minus $FEV_{1\ max}$ at baseline and reported as change per year. The same procedure was followed for FVC.

Blood sampling was performed on a subpopulation at follow-up. Atopic status was available for 625 woodworkers and 108 controls and was defined as a positive phadiatop (specific immunoglobulin E to any one of 12 common allergens).[30]

Analysis

When data were normally distributed, mean±SD is reported, otherwise the median (range) is reported. Univariate analyses and analyses stratified by sex and smoking were undertaken for categorical variables using χ^2 test. For continuous variables, independent-sample t tests or the Mann–Whitney U-test was used. In further analyses, association between cross-shift changes in FEV_1 and longitudinal changes in FEV_1 and FVC were analysed using multiple linear regression models adjusting for potential confounders (smoking, age, sex, height, weight gain and atopy). In analyses adjusting for smoking, smoking was expressed as pack-years in the follow-up period. For smokers the median follow-up time was 6.3 years; therefore, 7 pack-years were chosen as the cut-off point between light and heavy smokers.

When data on a variable were missing in an analysis, the observation with missing data was excluded, which led to a varied number of subjects across variables.

Unless otherwise stated, a significance level of 5% was used.

RESULTS

Participants versus non-participants

A flowchart of the study is shown in figure 1. At baseline, participants were slightly older compared with non-participants for woodworkers (39.0±12.2 vs 36.3±12.2 years; $p<0.001$) and for controls (38.9±9.7 vs 35.7±10.5 years; $p=0.02$). More non-participants were smokers at baseline compared with participants for woodworkers (49.3% vs 40.7%; $p=0.001$) and for controls (54.1% vs 45.9%; $p=0.06$). Non-participants tended to have lower LF expressed as FEV_1% pred. (97.5% vs 99.0%; $p=0.02$) compared with participants for the total cohort (97.4% vs 98.8%; $p=0.06$), for woodworkers and (97.9 vs 100.5; $p=0.14$) for controls. No differences were revealed for cross-shift changes in FEV_1 and when analyses were repeated stratified on smoking no differences in LF were revealed between participants and non-participants. In addition, non-participants tended to report at least one respiratory symptom at baseline more often than participants, significant for woodworkers (48.1% vs 40.9%; $p=0.02$), but similar for controls (49.3% vs 38.5%; $p=0.14$). No differences were observed for chronic bronchitis or self-reported asthma. No significant difference in baseline wood dust exposure was revealed between participants and non-participants.

A higher percentage of both woodworkers and controls contacted at the factories participated compared with workers invited by letter (figure 1).

Analyses for differences between participating woodworkers invited outside the factories compared with woodworkers at the factories revealed the former to have a significantly higher

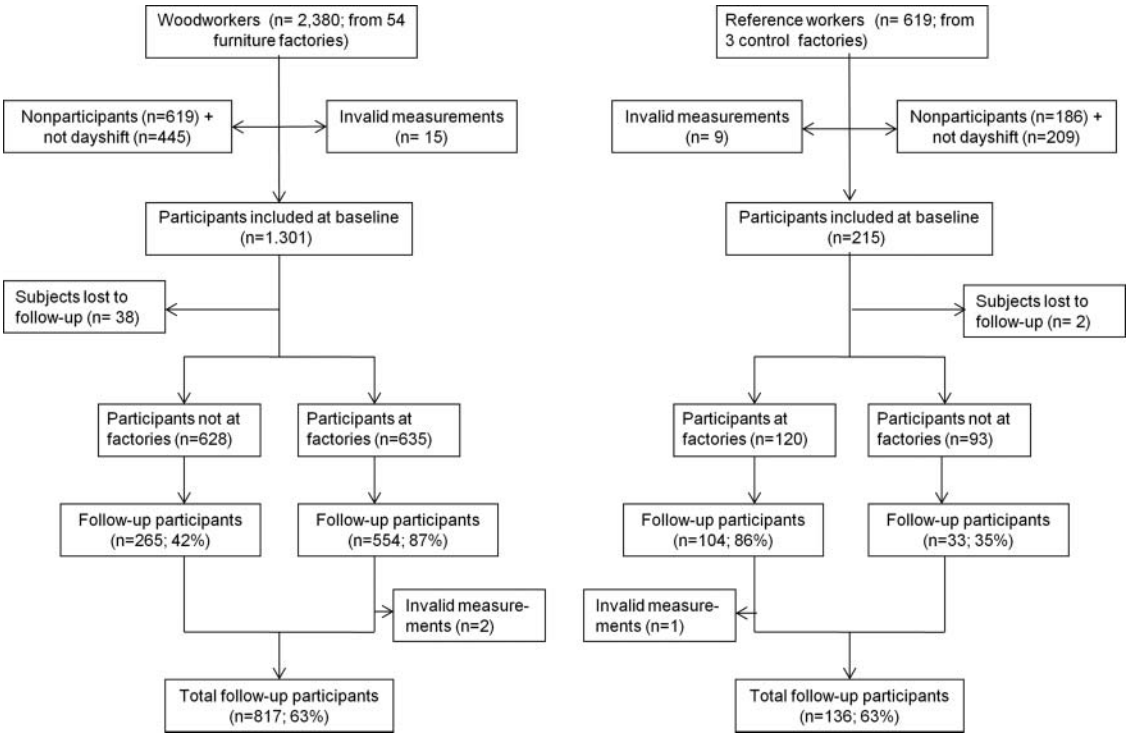

Figure 1 Flowchart of study population.

percentage of hay fever (16.7% vs 11.4%) and any respiratory symptom (47.0% vs 38.0%), including wheeze (20.5% vs 13.2%) at baseline, but revealed no differences in other respiratory symptoms (self-reported asthma, daily coughing and chronic bronchitis), smoking habits or LF expressed as FEV_1% pred. or percentage cross-shift change in FEV_1 at baseline.

A greater percentage of controls contacted outside the factories versus controls at the factories reported bronchitis at baseline (23.3% vs 4.4%) and lower FEV_1% pred. at baseline (99.1% vs 101.6%) along with a higher percentage of smokers (65.6% vs 44%; p=0.03). No differences in other respiratory symptoms, hay fever or percentage cross-shift change in FEV_1 were found.

Demographics of participants

Fewer woodworkers were female subjects compared with controls, and woodworkers tended to smoke less. Among the female woodworkers significantly fewer heavy-smokers (>7 pack-years during follow-up) were found compared with controls workers and female compared with male woodworkers had lower (p<0.01) median of cumulative wood dust exposure. No significant differences were found in baseline symptoms or atopy between exposed workers and controls or between male and female subjects, although male subjects tended to be more atopic than female subjects (table 1).

Lung function

Table 2 summarises cross-shift and longitudinal changes in FEV_1 and FVC stratified by sex and smoking. No significant differences were seen between woodworkers and controls of either sex. Smokers tended to have a greater cross-shift increase in FEV_1 and a greater longitudinal change in FEV_1 and FVC, significant for male subjects. For all workers, longitudinal changes in FEV_1 were negative with mean (SD) of −29.1 (41.8) ml/year and mean cross-shift changes in FEV_1 were positive (mean 0.70 ±212 ml). A total of 11.3% had a cross-shift change of more than 5%, with no differences between exposed and controls, male and female subjects, or smokers and non-smokers.

We found no correlation between cross-shift and longitudinal changes in FEV1. The correlation coefficient was −0.06, R^2 0.004, p=0.07.

Table 3 presents the results of multiple linear regression analysis for the association between relative cross-shift change in FEV_1 and absolute longitudinal change in LF stratified by sex and adjusted for smoking, age, height, weight gain and cumulative wood dust exposure. For female subjects, no association was revealed, but a borderline association was found for male subjects. For female subjects, a negative association between cumulative wood dust exposure and annual change in FEV_1 was revealed; the regression coefficient was −2.95 ml/year. As expected, smoking was related to decline in LF, most pronounced for heavy smokers, where significant negative regression coefficients were found in all strata.

Further regression analyses for the association between relative cross-shift FEV_1 change and longitudinal change in LFs were performed including different estimates on wood dust exposure (exposure status at baseline, log baseline exposure, quartiles of baseline exposure and quartiles of cumulative exposure) as well as analyses including atopy at follow-up for the subgroup of workers where atopic status was available. In addition, analyses including cross-shift decline as a dichotomous variable (±5% decline; <5% decline) and as quartiles of cross-shift decline were performed as well as analyses on relative longitudinal annual LF changes. None of the additional analyses changed the results substantially. For female workers, the analyses including quartiles of cumulative exposure revealed a negative association between the highest level of cumulative wood dust exposure above 4.76 mg year/m^3 and longitudinal changes in FEV_1 (not shown). For male subjects, a tendency of positive associations between relative cross-shift change and longitudinal change in FEV_1 was found across all analyses.

Table 1 Demographic characteristics of the cohort

	Males		Females	
	Woodworkers n=683	Control workers n=50	Woodworkers n=134	Control workers n=86
Age at BL years	39.0 (11.0)	42.0 (10.7)	39.0 (9.3)	37.2 (8.7)
Height, cm	179.2 (7.0)	177.8 (7.4)	166.7 (6.0)	167.6 (5.4)
Weight gain, kg	2.2 (5.5)	1.7 (6.1)	1.7 (6.6)	2.7 (6.0)
Missing	2	0	1	1
Smokers†	285 (42.0)	23 (46.0)	62 (47.0)	46 (54.1)
Missing	4	0	2	1
Smoking history				
<7 pack-years‡	142 (22.2)	14 (29.8)	35 (28.5)	21 (25.9)
≥7 pack-years‡	104 (16.3)	6 (12.8)	18 (14.6)	21 (25.9)
Missing	43	3	11	5
Any respiratory symptom at BL	250 (40.7)	20 (43.5)	48 (41.7)	27 (35.5)
Missing	69	4	19	10
Chronic Bronchitis at BL	65 (10.9)	6 (13.6)	5 (4.5)	5 (6.6)
Missing	86	6	23	10
Asthma§ at BL	34 (5.2)	3 (6.1)	10 (7.9)	5 (6.1)
Missing	25	1	7	4
FEV_1% of pred. BL	98.4±12.0	99.8±13.2	100.5±13.8	100.9±12.5
Missing	6	0	1	0
Follow-up time years	6.34 (0.58)	6.32 (0.27)	6.31 (0.57)	6.32 (0.24)
Atopy at follow-up¶	104 (19.9)	10 (27.0)	14 (13.7)	10 (14.1)
Missing	160	13	32	15
Wood dust at BL** mg/m^3	0.96 (0.17–0.78)		0.97 (0.17–3.78)	
Missing	45		7	
Cumulative wood dust** mg year/m^3	3.81 (0–7.07)*		3.26 (0–6.87)	
Missing	42		10	

Data are presented as mean±SD or n (%) of valid cases unless otherwise stated.
*p<0.01 male versus female subjects.
†Smokers are current smokers and ex-smokers who stopped smoking<2 years prior to baseline.
‡Pack-years smoking during follow-up calculated as pack-years at follow-up minus pack-years at baseline.
§Self-reported asthma.
¶Phadiatop was available for a subcohort of 733 participants.
**Median (range).
BL, baseline; FEV_1, forced expiratory volume in 1 s; pred., predicted.

Table 4 presents the regression analyses stratified on wood dust exposure, smoking and atopy for the association between relative cross-shift change in FEV_1 and annual changes in FEV_1 and FVC. The results from table 3 were confirmed, and no significant associations were revealed in any of the analyses.

In order to investigate the influence on participation on the factories as opposed to participation outside the factories, regression analyses were repeated including place of participation. Analyses stratified on participation place showed similar non-significant regression coefficients for relative cross-shift change in FEV_1 on longitudinal changes (table 4), but when the participation place was included in the model, a negative association between participation at the factory and longitudinal LF changes were seen. For annual change in FEV_1 the regression coefficient was −12.9 ml/year (p<0.001) and for annual change in FVC it was −13.6 ml/year (p<0.001).

DISCUSSION

To the authors' knowledge, the present study is the first study in the dry wood industry that investigates the possible association between cross-shift change in FEV_1 and subsequent longitudinal decline in LF.

In contrast to previous studies among workers exposed to organic dust including wood dust, the results from this study in a cohort of workers exposed to relatively low concentration of wood dust do not support cross-shift changes in FEV_1 to be predictive of an accelerated decline in LF. In the wood industry, only a small study has been performed by Dahlqvist and Ulfvarson. In a 27-month follow-up study of 15 wood trimmers compared with 26 sawmill workers they measured cross-week changes in FEV_1 and viable mould spores, but not wood dust or endotoxin exposure. They found a correlation between cross-week and longitudinal changes in FEV_1 for non-smoking wood trimmers.[14]

The association between acute and chronic LF changes has been most intensely studied in the textile industry. More results have been published from a 20-year follow-up study of 418 cotton workers and 417 silk workers from Shanghai textile mills. In the initial 5-year follow-up survey, the authors reported a cross-shift decline in FEV_1 of more than 5% to be strongly predictive of a subsequent 5-year decline in FEV_1 among cotton workers.[15] The mean change in FEV_1 was negative for cotton workers as well as for silk workers, and a total of 23.6% of cotton workers versus 13.2% of silk workers had a cross-shift decline of more than 5% as opposed to 11.3% in our study. The difference in cross-shift changes between cotton workers and silk workers was confirmed in further follow-ups of the cohort at approximately 5-year intervals. In addition, they reported that cotton dust was associated with an extra 10 ml/year in cotton workers, but not among silk workers, and that

Table 2 Changes in lung function of woodworkers and reference workers at baseline and follow-up stratified by sex and smoking

		Baseline cross-shift changes		Follow-up changes	
	Subjects, n	ΔFEV_1 ml	ΔFEV_1%	ΔFEV_1 ml/year	ΔFVC ml/year
Male workers					
Non-smokers					
Woodworkers	394	−14.0 (231.1)	−0.20 (6.01)	−25.2 (41.3)	−23.1 (45.5)
Control workers	27	−3.7 (175.4)	0.19 (4.11)	−22.5 (38.6)	−29.0 (41.0)
Smokers†					
Woodworkers	285	21.9 (220.3)*[1]	0.72 (6.32)*[2]	−36.8 (43.9)*[3]	−31.4 (50.4)*[4]
Control workers	23	0.0 (151.5)	0.45 (4.33)	−47.2 (55.7)	−45.4 (64.1)
Female workers					
Non-smokers					
Woodworkers	70	−8.0 (199.4)	0.10 (6.43)	−21.8 (37.0)	−15.8 (34.6)
Control workers	39	−1.3 (164.4)	0.24 (5.81)	−20.4 (27.1)	−17.4 (30.8)
Smokers†					
Woodworkers	62	−9.0 (158.9)	0.09 (6.12)	−34.2 (39.6)	−28.3 (39.3)
Control workers	46	16.3 (142.6)	0.59 (4.59)	−25.4 (38.7)	−22.6 (44.5)

Data are presented as mean (SD).
*[1]p=0.042; *[2]p=0.054; *[3]p=0.001; *[4]p=0.025 (smokers versus non-smokers).
†Smokers are current smokers and ex-smokers who stopped smoking <2 years prior to baseline.
Δ, difference; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

individuals with two or more cross-shift drops had significantly larger annual decline in FEV_1.[18]

Another 5-year follow-up study of cotton workers with different work shifts in the USA reported a negative association between a 200 ml cross-shift drop and longitudinal change in FEV_1 of 11.2, −34.6 and −35.4 ml/year for shifts 1, 2 and 3, respectively.[17]

In addition, a 2.5-year follow-up study of 587 Canadian grain workers and 111 civic workers reported annual decline in LF to be correlated to cross-week and cross-shift changes in LF at baseline.[13] This was confirmed in a 6-year follow-up study of 267 Canadian grain workers, especially among current and ex-smokers.[12 31]

In a 5-year follow-up study of 98 swine confinement workers with mean cross-shift changes in FEV_1 of −160 ml and an annual change of −54 ml, the authors reported baseline cross-shift change in FEV_1 and endotoxin exposure along with smoking and age as significant determinants of annual change in FEV_1.[19]

The current study is well powered compared with earlier studies on, for example, wood trimmers,[14] grain workers[12 13] and farmers[19] with the number of participants between 30 and 270, supporting our negative finding to be true. Though, an alternative reason for the negative results in this study may be the relatively small changes in cross-shift FEV_1. In accordance with other studies,[17] the overall cross-shift change of dayshift

Table 3 Multiple linear regression models on longitudinal changes in LF stratified by sex including cross-shift changes in FEV_1, cumulative wood dust exposure and smoking as independent variables

		LF changes at follow-up	
Independent variables	Subjects included (missing)	ΔFEV_1 ml/year Coefficient (95% CI)*	ΔFVC ml/year Coefficient (95% CI)*
Male workers	664		
ΔFEV_1%†	(69)	−0.49 (−0.99 to 0.00)	−0.00 (−0.54 to 0.54)
Wood dust exposure mg year/m^3‡		−0.94 (−2.68 to 0.79)	−1.24 (−3.12 to 0.63)
Smoking history			
<7 pack-years in period§		−4.12 (−11.60 to 3.36)	−3.68 (−11.78 to 4.41)
≥7 pack-years in period§		−16.39 (−24.84 to 7.93)	−14.56 (−23.71 to 5.42)
Female workers	192		
ΔFEV_1%†	(28)	−0.26 (−1.17 to 0.65)	0.22 (−0.66 to 1.10)
Wood dust exposure mg year/m^3‡		−2.95 (−5.57 to −0.34)	−1.78 (−4.33 to 0.76)
Smoking history			
<7 pack-years in period§		−1.66 (−13.90 to 10.58)	−9.11 (−21.01 to 2.78)
≥7 pack-years in period§		−21.86 (−35.51 to −8.21)	−16.65 (−29.91 to −3.38)

ΔFEV_1% has the same direction as LF changes at follow-up, that is, a positive regression coefficient indicates an association between decline in cross-shift FEV_1 and longitudinal LF.
*Further adjusted for height (continuous), weight-gain (continuous) and age (continuous).
†Cross-shift change in FEV_1 at baseline.
‡Cumulative wood dust exposure of woodworkers and control workers during follow-up, the latter with cumulative exposures of 0 mg year/m^3.
§With reference to non-smokers (newer smokers and ex-smokers who stopped smoking >years prior to the baseline study).
LF, lung function; ΔFEV_1, change in forced expiratory volume in 1 s; ΔFVC, change in forced vital capacity.

Table 4 Association between longitudinal changes in LF and cross-shift change in FEV_1 stratified by wood dust exposure, smoking, atopic status and place of participation adjusted for confounders in linear regression analyses

Independent variables	Subjects included (missing)	LF changes at follow-up	
		ΔFEV_1 ml/year Coefficient (95% CI)*	ΔFVC ml/year Coefficient (95% CI)*
Stratified by exposure†			
ΔFEV_1 cross-shift %‡	806	−0.29 (−0.74 to 0.16)	0.13 (−0.35 to 0.61)
Woodworkers	(11)		
ΔFEV_1 cross-shift %‡	129	−0.29 (−1.80 to 1.23)	0.55 (−1.07 to 2.17)
Control workers	(7)		
Stratified by smoking§			
ΔFEV_1 cross-shift %‡	412	−0.67 (−1.34 to 0.01)	−0.15 (−0.89 to 0.60)
+Smokers¶	(4)		
ΔFEV_1 cross-shift %‡	523	0.01 (−0.53 to 0.56)	0.40 (0.17 to 0.97)
−Smokers¶	(7)		
Stratified by atopy†§			
ΔFEV_1 cross-shift %‡	135	−0.48 (−1.27 to 0.32)	−0.35 (−1.28 to 0.58)
+Atopy[f]	(3)		
ΔFEV_1 cross-shift %‡	583	−0.43 (−0.96 to 0.09)	0.13 (−0.41 to 0.66)
−Atopy[f]	(12)		
Stratified by place of participation†§			
ΔFEV_1 cross-shift %‡	644	−0.21 (−0.78 to 0.35)	0.44 (−0.19 to 1.07)
+Factory**	(11)		
ΔFEV_1 cross-shift %‡	291	−0.31 (−0.93 to 0.30)	−0.19 (−0.80 to 0.41)
−Factory**	(7)		

ΔFEV_1% have the same direction as LF changes at follow-up, that is, a positive regression coefficient indicates an association between decline in cross-shift FEV_1 and longitudinal LF.
*Additional variables adjusted for in all the models: height (continuous), weight-gain (continuous) and age (continuous).
†Adjusted ± smoking.
§Adjusted ± wood dust exposure at baseline.
‡Cross-shift change FEV_1 baseline.
¶Smokers are current smokers and ex-smokers who stopped smoking <2 years prior to baseline.
[f]Atopic status at follow-up.
**Participation on factory versus invitation by letter.
LF, lung function; ΔFEV_1, change in forced expiratory volume in 1 s; ΔFVC, change in forced vital capacity.

workers in this study was positive due to the circadian rhythm. It cannot be ruled out that a greater cross-shift decline in FEV_1 at higher wood dust exposures than found in the Danish Furniture industry could influence the change in longitudinal LF indices in the same way as found among workers exposed to cotton dust and to dust and endotoxins in swine confinements.

In addition, endotoxin or other markers of microbial exposure may be of significance when considering the association between acute and chronic LF changes. Biohazards such as endotoxins and moulds in organic dust have been associated to both cross-shift decline in LF indices and an accelerated decline in FEV_1. A suspected high level of endotoxin is a common feature in industries, where an association between cross-shift and longitudinal change in FEV_1 has been reported.[13 15 17–19] Exposure to endotoxin and moulds among woodworkers have mainly been studied for workers exposed to fresh wood, but two studies have reported endotoxin levels of importance for health effects among workers in the dry wood industry.[4 32]

In order to evaluate possible effects of endotoxins in the present study, 29 measurements of endotoxin were performed on wood dust measurements from three factories participating in the study using the kinetic limulus amoebocyte test. We found very low levels of endotoxins with median (range) of 0.9 (0.3–6.3) EU/m^3 (unpublished data), substantially lower than the health-based recommended exposure limit of 90 EU/m^3 proposed by the Dutch Expert Committee on Occupational Safety.[33]

We have no theoretical explanation for the borderline significant association between an increasing FEV_1 during the day and a subsequent lower longitudinal decline in FEV_1 for male subjects. The results are probably random, but may be partly due to the data not being sufficiently adjusted for smoking. In addition, one could speculate that non-work related allergens might influence some workers with increased bronchial lability to have a steeper increase in FEV_1 during the working hours and at the same time result in a greater decline in longitudinal LFs; however, we find no evidence for this lability to be related to wood dust exposure.

The overall participation rate in the follow-up study was 63%, which may have caused selection bias. The dropout analyses showed a higher drop-out rate for both woodworkers and controls not employed at the factories (figure 1). This may contribute to a healthy workers selection in the cohort, as individuals who experience respiratory symptoms might be more prone to leave the industry. Non-participants were slightly younger, smoked more, and tended to have more respiratory symptoms and lower objective measures of LF at baseline compared with participants. The analyses for disparities between subjects invited outside the factories as opposed to subjects invited from the factories revealed a tendency for the former to have a higher percentage of baseline respiratory symptoms and among controls more smokers and lower objective measures of LF. However, while the longitudinal declines in LFs were higher among workers at the factories, no differences were found in baseline cross-shift

changes in LF. Including the place of participation in the analyses for change in longitudinal LFs did not change the size or the direction of the influence of cross-shift changes in FEV_1. The analyses were stratified or adjusted for sex and other relevant confounders including smoking. Therefore, it is unlikely that selection bias had a major influence on the result.

In conclusion, our study among workers exposed to low levels of dry wood dust does not support an association between acute and chronic decline in LF.

Funding This work has been funded by the Danish Work Environment Foundation, grant number 2002–23, the Danish Medical Research Council, grant numbers 22-02-0328 and 271-05-0570 and The Danish Health Insurance Fund, grant numbers 2002B133 and 2005B051.

Competing interests None.

Ethics approval Ethics approval was provided by the Ethics Committee for Viborg County, Denmark.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 Kauppinen T, Vincent R, Liukkonen T, *et al*. Occupational exposure to inhalable wood dust in the member states of the European Union. *Ann Occup Hyg* 2006;50:549–61.
2 Schlünssen V, Schaumburg I, Heederik D, *et al*. Indices of asthma among atopic and non-atopic woodworkers. *Occup Environ Med* 2004;61:504–11.
3 Beritic-Stahuljak D, Valic F, Cigula M, *et al*. Aerosol analysis, respiratory function and skin sensitivity testing in workers exposed to soft and hardwood dust. *Arh Hig Rada Toksikol* 1988;39:387–403.
4 Mandryk J, Alwais KU, Hocking AD. Work-related symptoms and dose-response relationships for personal exposures and pulmonary function mong woodworkers. *Am J Ind Med* 1999;35:481–90.
5 Schlünssen V, Sigsgaard T, Schaumburg I, *et al*. Cross-shift changes in FEV1 in relation to wood dust exposure: the implications of different exposure assessment methods. *Occup Environ Med* 2004;61:824–30.
6 Lin FJ, Dimich-Ward H, Chan-Yeung M. Longitudinal decline in lung function in patients with occupational asthma due to western red cedar. *Occup Environ Med* 1996;53:753–6.
7 Jacobsen G, Schaumburg I, Sigsgaard T, *et al*. Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Ann Agric Environ Med 2010;17:15–28.
8 Jacobsen G, Schaumburg I, Sigsgaard T, *et al*. Non-malignant respiratory diseases and occupational exposure to wood dust. Part II. Dry wood industry. *Ann Agric Environ Med* 2010;17:29–44.
9 Noertjojo HK, Dimich-Ward H, Peelen S, *et al*. Western red cedar dust exposure and lung function: a dose-response relationship. *Am J Respir Crit Care Med* 1996;154:968–73.
10 Jacobsen G, Schlünssen V, Schaumburg I, *et al*. Longitudinal lung function decline and wood dust exposure in the furniture industry. *Eur Respir J* 2008;31:334–42.
11 Becklake MR. Relationship of acute obstructive airway change to chronic (fixed) obstruction. *Thorax* 1995;50(Suppl 1):S16–21.
12 Tabona M, Chan-Yeung M, Enarson D, *et al*. Host factors affecting longitudinal decline in lung spirometry among grain elevator workers. *Chest* 1984;85:782–6.
13 Chan-Yeung M, Schulzer M, Maclean L, *et al*. A follow-up study of the grain elevator workers in the Port of Vancouver. *Arch Environ Health* 1981;36:75–81.
14 Dahlqvist M, Ulfvarson U. Acute effects on forced expiratory volume in one second and longitudinal change in pulmonary function among wood trimmers. *Am J Ind Med* 1994;25:551–8.
15 Christiani DC, Ye TT, Wegman DH, *et al*. Cotton dust exposure, across-shift drop in FEV1, and five-year change in lung function. *Am J Respir Crit Care Med* 1994;150:1250–5.
16 Christiani DC, Ye TT, Wegman DH, *et al*. Pulmonary function among cotton textile workers. A study of variability in symptom reporting, across-shift drop in FEV1, and longitudinal change. *Chest* 1994;105:1713–21.
17 Glindmeyer HW, Lefante JJ, Jones RN, *et al*. Cotton dust and across-shift change in FEV1 as predictors of annual change in FEV1. *Am J Respir Crit Care Med* 1994;149:584–90.
18 Wang X, Zhang HX, Sun BX, *et al*. Cross-shift airway responses and long-term decline in FEV1 in cotton textile workers. *Am J Respir Crit Care Med* 2008;177:316–20.
19 Kirychuk S, Senthilselvan A, Dosman JA, *et al*. Predictors of longitudinal changes in pulmonary function among swine confinement workers. *Can Respir J* 1998;5:472–8.
20 Schlünssen V, Schaumburg I, Taudorf E, *et al*. Respiratory symptoms and lung function among Danish woodworkers. *J Occup Environ Med* 2002;44:82–98.
21 Schlünssen V, Vinzents PS, Mikkelsen AB, *et al*. Wood dust exposure in the Danish furniture industry using conventional and passive monitors. *Ann Occup Hyg* 2001;45:157–64.
22 Vinzents PS. A passive personal dust monitor. *Ann Occup Hyg* 1996;40:261–80.
23 Schlünssen V, Jacobsen G, Erlandsen M, *et al*. Determinants of wood dust exposure in the Danish furniture industry—results from two cross-sectional studies 6 years apart. *Ann Occup Hyg* 2008;52:227–38.
24 Jacobsen G. Respiratory diseases and exposure in the Danish Furniture Industry: a 6 year follow-up. Ph.d Thesis. Faculty of Health Sciences, University of Aarhus 2007:1–139.
25 British Medical Research Council. Definition and classification of chronic bronchitis for clinical and epidemiological purposes. A report to the Medical Research Council by their Committee on the Aetiology of Chronic Bronchitis. *Lancet* 1965;1:775–9.
26 Burney PG, Luczynska C, Chinn S, *et al*. The European Community Respiratory Health Survey. *Eur Respir J* 1994;7:954–60.
27 Millller MR, Hankinson J, Brusasco V, *et al*. Standardisation of spirometry. *Eur Respir J* 2005;26:319–38.
28 Danish Lung Association. *Spirometry. A recommentdation. (En rekommandation fra Dansk Lungemedicinsk selskab)*. Copenhagen: Danish Lung Association, 1996:5–17.
29 Omland O, Sigsgaard T, Hjort C, *et al*. Lung status in young Danish rurals: the effect of farming exposure on asthma-like symptoms and lung function. *Eur Respir J* 1999;13:31–7.
30 Cantani A, Ferrara M, Barbieri C, *et al*. Evaluation of new test (Phadiatop) for the screening of respiratory allergic disorders in children. *Ann Allergy* 1990;64:158–61.
31 Becklake MR. Grain dust and lung health: not just a nuisance dust. *Can Respir J* 2007;14:423–5.
32 Harper M, Andrew ME. Airborne endotoxin in woodworking (joinery) shops. *J Environ Monit* 2006;8:73–8.
33 Health Council of the Netherlands. *Endotoxins. Health-based recommended occupational exposure limit*. The Hauge: Health Council of the Netherlands, 2010; publication no. 2010/04OSH.