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ORIGINAL ARTICLE

Respiratory symptoms and cross-shift lung function in relation to cotton dust and endotoxin exposure in textile workers in Nepal: a cross-sectional study

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ABSTRACT

Objectives Inhalation of a cotton-based particulates has previously been associated with respiratory symptoms and impaired lung function. This study investigates the respiratory health of Nepalese textile workers in relation to dust and endotoxin exposure.
Methods A total of 938 individuals from four sectors (garment, carpet, weaving and recycling) of the textile industry in Kathmandu, Nepal completed a health questionnaire and performed spirometry. A subset (n=384) performed cross-shift spirometry. Personal exposure to inhalable dust and airborne endotoxin was measured during a full shift for 114 workers.
Results The overall prevalence of persistent cough, persistent phlegm, wheeze ever, breathlessness ever and chest tightness ever was 8.5%, 12.5%, 3.2%, 6.5% and 12.3%, respectively. Symptoms were most common among recyclers and least common among garment workers. Exposure to inhalable dust significantly predicted persistent cough and chest tightness. Exposure to endotoxin did not have any independent predictive effect. Significant cross-shift reduction in forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC) were found ($p<0.001$ for both) being largest for FEV_1 in the recyclers (−143 mL), and least in the garment workers (−38 mL; $p=0.012$). Exposure to inhalable dust predicted a cross-shift reduction in FEV_1.
Conclusions This study is the first to investigate the respiratory health of Nepalese cotton workers. The measured association between inhalable dust exposure and reporting of respiratory symptoms and across-shift decrement in FEV_1 and FVC indicates that improved dust control measures should be instituted, particularly in the recycling and carpet sectors. The possible role of other biologically active agents of cotton dust beyond endotoxin should be further explored.

What this paper adds

- Workers in the Nepalese textile industry experience high concentrations of airborne endotoxin.
- Despite high levels of endotoxin exposure, inhalable dust appears to be more closely related to cross-shift change in lung function and symptoms than endotoxin.
- The possible role of other biologically active agents in cotton dust beyond endotoxin should be further explored.

INTRODUCTION

Cotton workers are exposed to dust originating from natural and synthetic fibrous material.[1 2] Cotton is often contaminated with other ubiquitous natural microbial elements, such as endotoxin, which are released into the environment during the processing of cotton. Following Schilling's work in Manchester cotton mills in the 1950s and early 1960s, it has been well established that the inhalation of cotton dust and endotoxin can cause respiratory health effects, notably cough, phlegm, chronic bronchitis, asthma and byssinosis.[3–5]

The clinical evaluation of cotton dust-induced pathology has largely focused on lung function. Such studies are crucial in establishing aetiological agents and causative relationships.[6] Several different patterns of change in lung function may develop after exposure to cotton dust. Acute decrements in lung function have been observed in cotton textile workers in periods of early naïve exposure which are often related to concentrations of dust, grade of cotton used and various other microbial agents and their toxins.[7] Cross-shift changes in forced expiratory volume in 1 s (FEV_1) are considered as acute and reversible,[1 8 9] while longer term exposure to cotton dust is associated with significant loss of lung function. A longitudinal study conducted on 408 cotton workers and 417 silk workers over 20 years reported that exposure to cotton dust was associated with a 10 mL/year decrement in 5-year annualised FEV_1 decline. Moreover, every 10 mL cross-shift drop in FEV_1 was associated with an additional 1.5 mL/year loss in annualised FEV_1 decline.[10]

Gram-negative bacterial endotoxin contaminated cotton dust has been linked to both acute cross-shift changes[11–13] and chronic respiratory disease in cotton textile workers with some studies reporting a significant exposure–response relationship.[1 14]

The cotton textile industry is one of the oldest industries in Nepal employing around 200 000 people and accounting for more than half of the country's export business in 2001.[15] The vast majority of workers in these industries are exposed to organic dust, but very little attention is given to the measurement of dusts and other respiratory toxin exposures and their health impact. We

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describe here findings from the first study of the respiratory health of textile workers in Nepal in relation to particulate and endotoxin exposures.

METHODS

We conducted a cross-sectional survey from March 2008 to March 2009 in Kathmandu, Nepal. The survey was carried out in four different sectors of the textile industry: garment, carpet, weaving and recycling. The garment factories produced mostly cotton garments along with some hemp and linen garments, while the carpet sector manufactured woollen carpets along with some cotton and silk carpets. The weaving factories made cotton clothing along with mixtures of wool and polyester clothing, and the recycling sectors produced fibres using all sorts of fabric waste from nearby weaving and garment factories. More details of the nature of these sectors have been reported previously.[16] Since no government department holds a listing of industries, the workplaces were largely identified by those recorded in the local telephone directory and from word of mouth. Ethical approval for the study was obtained from the Nepal Health Research Council.

The respiratory health of the workers was assessed using a questionnaire and spirometry. The respiratory questionnaire was based on the International Union Against Tuberculosis and Lung Disease (IUATLD) and Global Initiative for Obstructive Lung Diseases (GOLD) questionnaires as well as the cotton-specific questionnaires used in Manchester, UK.[17] The questionnaire was translated into Nepali and validated by back translation into English and was piloted prior to its use in the study. The questionnaire was delivered by the researcher in local dialect. Normally, the work week was 6 days long, with 1 day off on a Saturday. Almost all of the workers worked a day shift.

The questionnaire data were entered dually into SPSS (V.20, SPSS Inc, Chicago, Illinois, USA) and the two files were then compared to remove transcription errors.

Pulmonary function testing was carried out using an Easyone Spirometer (ndd Medical Technologies Inc Andover, Massachusetts, USA) according to the American Thoracic Society (ATS) Guidelines.[18] The test was carried out on each worker on his or her return to work after a 36 h rest and before they started work. Hence, spirometry was generally performed on the first day of a working week (Sunday) preshift and post-shift, cross-week readings being completed by taking measurements on Friday any time during the shift. Owing to the uncertainty of the work schedule and regular power cuts in these industries, cross-shift measurement was carried out in all the available workers agreeing to participate. The purpose of the test was clearly explained to each worker, the test being demonstrated twice. Each worker performed expiratory manoeuvres until the 'session complete' remark was shown on the spirometer device. The quality of the spirometry data was assessed by one of the authors (JGA) by inspection of both volumetric and flow-volume traces. The best of three reproducible values was used in the analysis. Predictive values were derived using the ERS/Zapletal reference values and the data were marked as Asian.[19]

Personal exposure to total inhalable dust and endotoxin was measured, the results of which have been reported previously.[16] Briefly, personal exposure to inhalable dust was measured using an Institute of Occupational Medicine (IOM) sampling head and the dust work shift concentration was determined gravimetrically. Endotoxin levels were measured using the Limulus Amoebocyte Lysate (LAL) test assay (Charles River Laboratories BP L'Arbresle Cedex, France). Exposure was assessed on the basis of industrial sector, task involved and the size of the factory and any control measures used. Workers who did not have personal dust and endotoxin exposure measurements were ascribed the geometric mean (GM) values of all workers within the same occupation within that sector. To investigate the relationship between exposure, respiratory symptoms and lung function, workers were given a personalised occupational exposure estimate of both cotton and endotoxin determined by individual sampling (n=114) or by the specific occupation carried out by them (n=557). No exposure values were ascribed to the individuals from occupational groups and industries where exposure assessment was not carried out (n=267).

First, a series of univariate analyses were made to relate lung function (forced vital capacity (FVC), FEV_1, and FEV_1/FVC) and respiratory symptoms (cough, phlegm, chest tightness, breathlessness and wheeze) with the following covariates; age, sex, height, smoking data, fuel use, literacy years worked in the current industry, years worked in the cotton industry textile sector, exposure to dust, exposure to endotoxin and work hours. A forward stepwise multiple regression analysis was carried out to identify factors independently influencing the dependent variable of lung function (FEV_1/FVC) and the respiratory symptoms. Covariates were entered into the model in the order of significance obtained from the univariate analysis. A cut-off value of $p<0.1$ was set for the covariates to be entered in multivariate analysis; however, age, sex, height, dust and endotoxin were always entered into the multivariate model even if they were not significant in the univariate analysis.

RESULTS

Altogether, 938 workers completed the interviewer-delivered questionnaire, representing 92% of workers available at the sites visited. The median age of all workers was 25 (IQR 20–32) years with a range of 16–65 years. Nearly two-thirds of the investigated workers were male (63%, n=593). Overall, 29.5% of the workers reported that they were current smokers. On average, workers had worked 8 (IQR 3–5) years in the cotton industry. The characteristics of all investigated workers by textile sector are presented in table 1.

Dust and endotoxin exposure

Personal exposure to inhalable dust was measured for a total of 114 workers across the four industrial sectors (figure 1). Exposures were lowest and similar in the weaving and the garment sectors (GM=0.30 mg/m^3 for both) and highest in the recycling sector (GM=3.36 mg/m^3). The exposure level in the carpet industry fell between the weaving and the recycling sectors (GM=1.16 mg/m^3). There was a large variation in the endotoxin concentrations with very high levels in the recycling sector (GM=5110 EU/m^3) followed by the weaving sector (GM=2440 EU/m^3) and the carpet sector (GM=678 EU/m^3). Exposure was lowest in the garment sector (157 EU/m^3). Overall, there was a significant correlation between inhalable dust and endotoxin considering all the studied textile industry sectors ($r=0.43$; $p<0.001$). Full details of measured exposure concentrations are described elsewhere.[16]

Respiratory symptoms

Overall, the prevalence of persistent cough, persistent phlegm, chest tightness ever, breathlessness ever and wheeze ever was 8.5%, 12.5%, 12.3%, 6.5% and 3.6%, respectively. The prevalence of symptoms was highest in the weaving sector and lowest in the garment sector (table 1). Persistent cough was significantly predicted by exposure to inhalable dust and persistent phlegm

Table 1 Demographic, smoking, employment history and respiratory symptoms by textile sector (N=938)

Characteristics	Garment (n=223)	Carpet (n=224)	Weaving (n=271)	Recycling (n=220)	Total (n=938)
Median (IQR)					
Age#	25 (20–32)	35 (30–40)	27 (22–35)	30 (22–40)	30 (23–37)
Years worked in cotton industry#	5 (3–11)	15 (10–20)	5 (2–11)	8 (2–16)	8 (3–15)
Years worked in this industry#	2 (0.4–5)	8 (5–13)	2 (0.3–2)	5 (1–12)	3.5 (1–9)
Hours worked per week*	60 (48–72)	54 (48–60)	60 (48–72)	56 (48–72)	54 (48–70)
Per cent (n)					
Male#	80 (178)	17 (38)	65 (175)	92 (202)	63 (593)
Literacy#	92 (204)	51 (115)	81 (219)	53 (117)	68 (654)
Ever-smoker#	29 (65)	35 (78)	35 (94)	53 (117)	38 (354)
Persistent cough*	4 (9)	10 (23)	8 (22)	12 (26)	9 (80)
Persistent phlegm#	12 (26)	2 (25)	11 (30)	16 (36)	13 (117)
Chest tightness ever	8 (17)	12 (27)	15 (41)	14 (30)	12 (115)
Breathlessness ever#	1 (2)	6 (13)	11 (29)	8 (17)	7 (61)
Wheeze ever*	2 (4)	3 (6)	16 (17)	3 (7)	4 (34)

p Values #<0.001 *<0.05 when compared across the sector.

was significantly predicted by overall work years spent in cotton industry, and currently working in textile sector. Working in the carpet and recycling sectors was associated with increased risk and working in the weaving sector had a protective effect with respect to cough and phlegm. Sex, height and exposure to inhalable dust were significant predictors of chest tightness. Height, and working in the carpet, weaving or recycling sector predicted for breathlessness (table 2). Exposure to endotoxin was not associated with any of the respiratory symptoms in the univariable analysis or in the multivariate model (see online supplementary appendix 1).

Lung function

Valid spirometry data were available for 808 individuals (86%); 9 participants had missing data due to absence, refusal or not being able to perform the test for health or personal reasons (altogether n=9) and 121 did not meet the ATS criteria (figure 2). There was no difference in age, proportion of males/females, literacy, smoking status and work years in the cotton industry between individuals providing valid and invalid spirometry. The baseline lung function data included the values obtained from either the Sunday morning or the Sunday evening spirometry (n=701). Owing to logistical constraints, some workers (n=107) performed spirometry on days other than a Sunday. To avoid day-to-day variation in lung function, data from these workers were not included in our analysis. Overall, the mean percentage predicted values of FEV_1, FVC and FEV_1/FVC% of all workers regardless of sector were 82.7, 86.0 and 100.2, respectively. FEV_1, FVC and FEV_1/FVC% indices were higher in the garment workers followed by the recyclers, the weavers and the carpet workers, respectively (table 3). Percentage predicted FEV_1 and FVC were similar across the sectors, but percentage predicted FEV_1/FVC varied by sector ($p<0.001$), being highest in the garment workers, followed by recyclers, weavers and carpet workers.

A total of 384 workers (229 male and 155 female) performed cross-shift spirometry. A significant cross-shift reduction in FEV_1 and FVC was measured when considering all textile workers

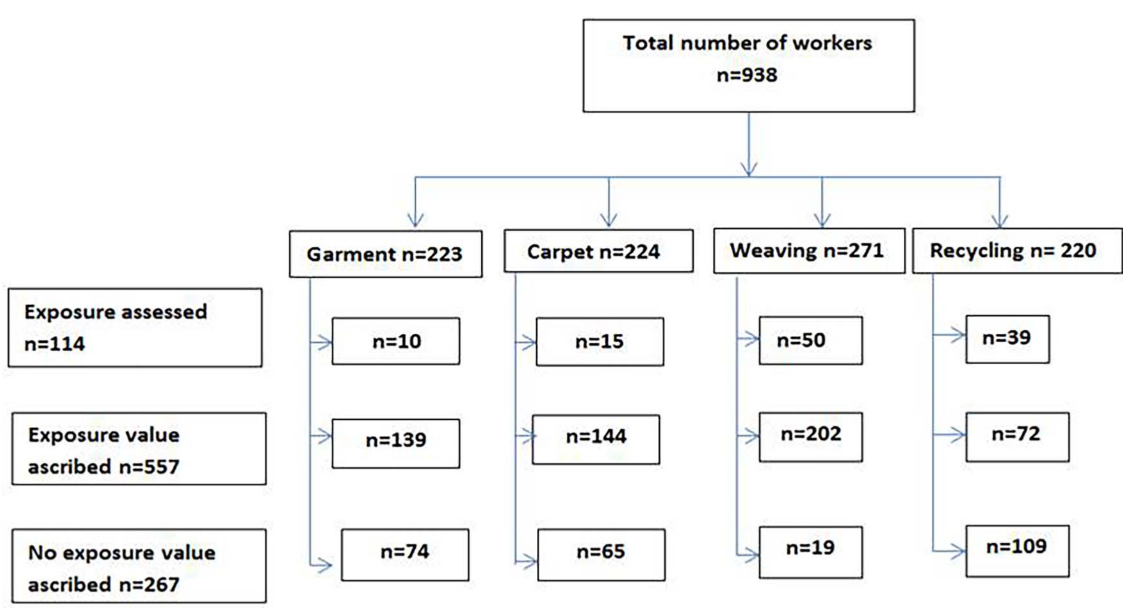

Figure 1 Flow chart showing the number of exposure measurements and number of ascribed values by sector.

Table 2 Logistic regression analysis: independent predictors of respiratory symptoms

Respiratory symptoms	OR	95% CI Upper	95% CI Lower	p Value
Persistent cough (n=96)*				
Exposure to inhalable dust	1.69	1.01	2.82	0.04
Persistent phlegm (n=123)†				
Garment	1.00			
Carpet	1.84	0.18	19.21	0.61
Weaving	0.37	0.13	1.04	0.06
Recycling	2.99	0.67	13.31	0.15
Work years in cotton industry	1.14	1.04	1.26	0.01
Chest tightness ever (n=92)‡				
Sex	0.31	0.10	1.00	0.05
Height	0.91	0.85	0.98	0.01
Exposure to inhalable dust	2.02	1.23	3.30	0.01
Breathlessness ever (n=666)§				
Garment	1.00			
Carpet	7.42	0.92	59.87	0.08
Weaving	15.39	2.06	115.10	0.01
Recycling	10.76	1.32	87.87	0.03
Height	0.98	0.96	1.00	0.06

*Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, sex, height, literacy, years worked in current industry, years worked in cotton industry, exposure to dust and exposure to endotoxin.
†Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, height, sex, height, literacy, years worked in current industry, years worked in cotton industry, exposure to dust and exposure to endotoxin.
‡Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, sex, height, work years in current industry, exposure to dust and exposure to endotoxin.
§Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, sex, height, exposure to dust and exposure to endotoxin.

together ($p<0.001$). Overall, cross-shift reductions in the absolute and percentage predicted respiratory indices were similar across the sectors regardless of gender and smoking status. When compared across the sectors, cross-shift reduction in FEV_1 was found to be largest in the recyclers (−143 mL), followed by the carpet workers (−110 mL), the weavers (−43 mL) and the garment workers (−38 mL; p=0.012; table 4). Exposure to inhalable dust was significant predictor of cross-shift reduction in FEV_1, age and working in the carpet sector were significant predictors of FVC, and working in the recycling sector and age were significant predictors of cross-shift change in FEV_1/FVC (table 5). Exposure to endotoxin was not associated with any of the cross-shift parameters of lung function.

DISCUSSION

This is the first study of the respiratory health of cotton workers in Nepal in relation to cotton dust exposure. The study uses previously validated diagnostic criteria and measurement approaches and has incorporated an exposure assessment protocol allowing us to classify individual inhalable dust and endotoxin exposures from data collected within each work sector. The major strength of the study is the large sample size with comparisons across sectors, large data on cross-shift measurements and direct measures of exposure to both cotton dust and endotoxin.

The prevalence of persistent cough and phlegm in this study was very similar to that of other studies,[9 11 17] although surprisingly there were no significant differences in the reporting of symptoms between current smokers, ex-smokers and non-smokers in our study. This finding contradicts the findings from previous studies which reported all respiratory symptoms except byssinosis to be significantly more frequent in smokers than non-smoking cotton workers.[2 20] The low prevalence of reported smoking in the current study (29.5% of current smokers compared to western cotton workers, 59.2% in the British cotton workers[2] and 46.4% in German cotton workers[1]) may be the reason for this difference, especially as we did not objectively confirm smoking status by, eg, use of salivary cotinine. Not only is the prevalence of smoking low in this study, but also the lifetime consumption of cigarettes among ever-smokers (3.2 pack-years) is a much lower compared to the other studies: 15.8 pack-years among Chinese cotton workers,[8] 17.7 and 15.5 pack-years among British cotton workers with bronchitis and British man-made fibre workers, respectively.[2]

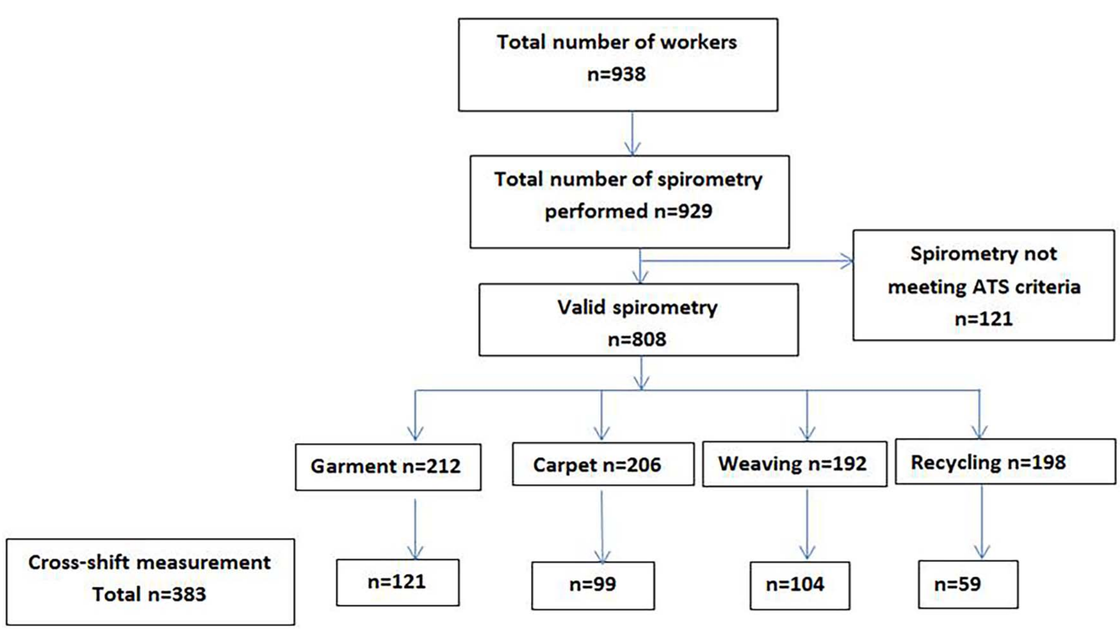

Figure 2 Flow chart showing lung function measurement by sector (ATS, American Thoracic Society).

Table 3 Absolute and percentage predicted values of lung functions by textile sector (N=701)

Textile sectors	Absolute			Predicted		
	FEV_1 (L) Mean (SD)	FVC (L) Mean (SD)	FEV_1/FVC Mean (SD)	%FEV_1 Mean (SD)	%FVC Mean (SD)	%FEV_1/FVC Mean (SD)
Garment (205)	2.89 (0.60)	3.42 (0.66)	0.85 (0.07)	82.94 (14.63)	83.85 (13.87)	102.68 (7.39)
Carpet (195)	2.23 (0.55)	2.74 (0.62)	0.81 (0.07)	81.90 (16.01)	86.17 (15.30)	98.79 (8.47)
Weaving (188)	2.70 (0.71)	3.31 (0.75)	0.81 (0.08)	82.18 (15.29)	86.57 (13.99)	98.98 (9.58)
Recycling (113)	2.80 (0.59)	3.42 (0.63)	0.82 (0.07)	84.30 (13.75)	87.84 (13.37)	100.27 (8.17)
Total (701)	2.64 (0.67)	3.20 (0.73)	0.82 (0.07)	82.68 (15.05)	86.02 (14.27)	100.22 (8.58)
p Value*	p<0.001	p<0.001	p<0.001	p=0.56	p=0.06	p<0.001

*p Value from one way ANOVA test for the intersector comparison of lung function parameters.
ANOVA, analysis of variance; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

In our study, personal exposure to dust independently predicted persistent cough and chest tightness. The importance of dust exposures, independent of smoking, in the aetiology of respiratory symptoms has been recognised in other industries such as grain and coal mining.[21 22] Intriguingly, endotoxin was not associated with any of the respiratory symptoms and, when included in the multivariate model, did not have any independent predictive effect. These findings corroborate the earlier findings from the cross-sectional study in cotton workers in Turkey,[9] but contradict those of a German textile mill that reported a fourfold increased risk of cough in individuals exposed to high endotoxin concentrations, compared to those exposed to low levels of endotoxin.[23] The range of endotoxin exposure in the Chinese and German studies was 25–7590 EU/m^3 and 9–7177 EU/m^3, respectively. Despite the high level of endotoxin exposure seen in the Nepalese textile industry (range 86–26 300 EU/m^3), there is no obvious explanation for the absence of its adverse effect on respiratory symptoms. Dust and endotoxin were both used as covariates in the same model, since the two were moderately correlated (r=0.37; p<0.001), this might have led to endotoxin not being a significant predictor of outcome in multivariate models. However, the absence of a significant association between endotoxin exposure and symptoms even in the univariate analysis may also be interpreted as casting doubt on the importance of endotoxins in the aetiology of respiratory symptoms in this setting.[24]

Earlier studies have reported a different prevalence of byssinosis (defined as chest tightness on the first day of the working week) in cotton workers.[25–27] Contrary to our expectation, this temporal symptom of chest tightness was not seen in our study. Earlier studies have demonstrated that byssinosis is rare in workers with <15 years' experience of work in the cotton spinning industry,[25] so the young age of the workers and the short work tenure of this population may explain the absence of byssinotic symptoms in the industry. Moreover, the early stages of cotton processing was not involved in the cotton industry involved in this study, hence the cotton handled was not 'biologically active'. Work schedules were often not followed properly by the workers studied due to regular power cuts. Many worksites were home based and used to run without a break even during the weekends. Consequently, these workers may have found it difficult to answer questions relating to day-specific patterns of their symptoms. Another explanation might be the healthy worker effect with affected individuals having left the industry because of symptoms. Evidence of a healthy worker effect has been reported in earlier studies of cotton workers regarding the prevalence of symptoms.[8 26] A high labour turnover was reported in the Turkish cotton industry, 13% of the naive cotton workers leaving the job within the first week.[9] However, it was not possible to assess this effect in this study due to its cross-sectional design. Moreover, the lack of a national database on the health status of the Nepalese population made it impossible to find out whether the health of cotton workers is any different from the health of the general population.

The mean percentage predicted FEV_1 and FVC values for the workers who participated in this study were lower than those reported in earlier studies,[1 28–30] but similar to those of other studies conducted in Asian countries like India and Iran.[31 32] The most striking result of our study is the significant cross-shift decrement in FEV_1 and FVC in all the workers on the first day of the working week. The decrement was more pronounced in the recycling sector compared to the other sectors of the textile industry where the exposure to dust was high and was observed in both men and women. Exposure to inhalable dust was a predictive factor for cross-shift changes in the indices of dynamic lung function. Our findings corroborate those of previous studies which reported cross-shift reductions in FEV_1 with greater exposure to dust[20 33 34] but compare with the findings from other studies which reported no associated with cotton dust levels.[1 9 11 12]

The R^2 values for the models were relatively small (R^2=0.47), suggesting that current dust exposure does not explain the majority of the variation in the cross-shift changes in $FEV_{1.}$ Various other factors such as lack of awareness to health and safety issues, not wearing personal protective equipment, lack of adequate ventilation, using a broom for cleaning purposes, and other underlying comorbid conditions may have affected the lung function in these workers. Also, it might have resulted from exposure misclassification, as this study did not measure the personal dust exposure for every individual; rather, it ascribed the GM depending on the specific task. To assess this, we carried out sensitivity analysis restricting the data to 114 workers who had personal exposure data. The results were slightly different from the main results; working in the weaving sector was the only predictor for all cross-shift parameters for lung function. Only 57 of 114 individuals had performed the cross-shift spirometry and this variability in the result suggests that exposure misclassification may have affected our results to some extent. Also, there may have been an analytical error in the assessment of endotoxin as the process is complicated, involving extraction of filters, storage of extracts and dilution and testing in the LAL assay.[35]

Unlike other studies,[11 12 14 28 36] this study did not find any significant relationship between measured endotoxin exposure and reduced cross-shift lung function. Endotoxin exposure was

Table 4 Absolute and percentage predicted values of cross-shift lung functions across the textile sector (N=384)

Textile sectors	Δ* FEV_1 (mL) Mean (95% CI)	Δ FVC (mL) Mean (95% CI)	%FEV_1/FVC Mean (95% CI)	Δ %FEV_1 Mean (95% CI)	Δ %FVC Mean (95% CI)	Δ %FEV_1/FVC Mean (95% CI)
Garment (121)	−38.21 (−77 to 0.57)	−53.16 (−103.82 to −2.50)	0.13 (−0.67 to 0.92)	−1.19 (−2.29 to −0.10)	−1.56 (−2.79 to −0.33)	0.25 (−3.38 to 1.67)
Carpet (99)	−109.87 (−169.76 to 49.98)	−148.11 (−222.49 to −73.72)	0.21 (−0.68 to 1.11)	−4.36 (−6.75 to −1.97)	−4.95 (−7.51 to −2.38)	0.21 (−5.68 to 0.36)
Weaving (99)	−43.34 (−86.35 to −0.34)	−39.89 (−94.70 to 14.92)	−0.15 (−0.87 to 0.56)	−1.32 (−2.66 to 0.02)	−1.27 (−2.72 to 0.17)	−0.08 (−4.50 to −0.33)
Recycling (59)	−143.42 (−205.91 to −80.92)	−96.59 (−169.41 to 23.77)	−1.81 (−2.98 to 0.63)	−4.32 (−6.10 to −2.54)	−2.54 (−4.39 to −0.70)	−2.22 (−10.03 to −3.56)
Total (384)	−74.25 (−99.13 to −49.38)	−80.68 (−111.76 to −49.61)	−0.22 (−0,66 to 0.21)	2.52 (−3.35 to −1.68)	−2.49 (−3.39 to −1.59)	0.24 (−4.01 to −1.34)
p Value†	0.012	0.054	0.019	0.005	0.014	0.019

Δ*=after shift value-before shift value.
†p Value from a one-way ANOVA test for the intersector comparison of cross-shift lung function parameters.
ANOVA, analysis of variance; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

not associated with any of the respiratory parameters in the univariate and multivariate analysis. The results of this study are in accordance with other cross-sectional studies which reported a significant cross-shift drop in lung function which bore no relationship with measured endotoxin exposure.[1 9 23] However, our results differ from the findings of previous longitudinal studies in cotton workers which have demonstrated that prolonged exposure to endotoxin may lead to chronic respiratory impairment and diminished lung function.[10 14] Given the cross-sectional nature of our study, it was not possible to examine the long-term effect of endotoxin exposure in our study. However, the lack of association with reduced cross-shift lung function in our study suggests that there may be other influential exposures which determine acute change in ventilatory function in Nepalese cotton workers. Also, the workers were exposed purely to cotton dust as well as to other non-cotton textiles such as wool and silk, which may explain to some extent dust being a stronger predictor of outcome than endotoxin.

All the respiratory symptoms were based on the interviewees' response, and thus the self-reported health data may have been influenced by reporting bias from the fear of losing employment in the current economic situation in Nepal. In addition, the effect of recall bias cannot be ruled out in this study. Moreover, much of the Nepalese population consider wheeze, breathlessness and bringing up phlegm as normal conditions and this may result in under-reporting of symptoms, which in turn might influence the true risk associated with exposure.[37] The workplaces were not randomly selected and the measurements were not randomly taken because of both logistical and time constraints. However, walk-through surveys of the factories included in the study showed no important differences in infrastructure or work processes compared to those that were not revisited for practical reasons. The personal sampling collected in the study may not represent the actual exposure of all the individuals as the GM was ascribed to the workers depending on the task and the worksite. However, personal visits to the workplace showed no substantial difference in the infrastructure in the different workplaces; thus, it can be assumed that exposures were broadly representative. Missing and inferred exposure values and missing data on spirometry may have biased the finding of this study. In addition, multiple comparisons may have influenced the results of this study as several hypotheses were tested simultaneously, increasing the possibility of a false-positive test. Various statistical techniques, such as the Bonferroni correction and Benjamini-Hochberg procedure, have been developed to overcome such problems. No such corrections were applied in this study as clear hypotheses were established prior to data collection.

The large sample size, geographical and socioeconomic diversity of the workforce and inclusion of multiple textile sectors make the findings of this study relevant across the cotton industry in Nepal and may be applicable to those employed in the cotton industry in other Asian countries such as Bangladesh, India and Pakistan which feature similar sociodemographic characteristics and occupational settings. However, the findings of this study have limited relevance to cotton workers in developed countries where the population parameters are different, industrial settings are more modernised and industrial processes tend to be mechanised. Nevertheless, the findings of this study are significant in terms of understanding the science behind the effect of organic dust exposure and its effect on the respiratory health of cotton workers around the globe.

In summary, this study gives insight into dust and endotoxin exposures across a broad spectrum of workplace sectors within

Table 5 Multiple linear regression analysis: independent predictors of the cross-shift changes in lung function

Lung function	β	95% CI Upper	95% CI Lower	R^2 value for the model	p Value
Cross-shift FEV_1 (n=312)*					
Exposure to inhalable dust	−57.6	−134.30	−76.8	4.7	<0.001
Cross-shift FVC (n=312)†					
Working in the carpet sector	−115.27	−193.49	−37.04	6.0	<0.001
Age	−5.05	−8.70	−1.40		0.01
Cross-shift FEV_1/FVC (n=312)‡					
Working in the recycling sector	−1.66	−2.90	−0.41	2.00	0.01
Age	0.06	0.01	0.11		0.02

*Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, sex, height, exposure to dust and exposure to endotoxin.
†Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, sex, height, literacy, exposure to dust and exposure to endotoxin.
‡Covariates used in the model: textile sector (garment, carpet, weaving, recycling), age, sex, height, work years in current industry, hours worked per week, exposure to dust and exposure to endotoxin.

the textile industry in Nepal and describes the impact on lung function, particularly across-shift changes in relation to dust and endotoxin exposure. Inhalable dust appears to be more closely related to cross-shift change in lung function and symptoms, and once accounted for, endotoxin does not significantly add to the regression analysis. This suggests that despite high levels of endotoxin exposure, inhalable dust is the driver for these effects and attention should turn to what might be the toxic component in this dust other than endotoxin.

Simple control measures such as ventilation, use of personal protective equipment, regular cleaning of equipment and good housekeeping practices should be incorporated in the first instance to reduce workers' exposure to both inhalable dust and airborne endotoxin. Employers across the textile industry need to be encouraged to make more rigorous attempts to control exposures and this may be best driven by the influence of Western companies who purchase cotton goods from Nepal. In addition to the health effect of occupational exposure to cotton dust, the workers are concomitantly exposed to other domestic and environmental pollutants which may have an adverse effect on their respiratory health. Hence, a well-designed study addressing these potential determinants would make a significant contribution to the understanding of respiratory health of cotton textile workers in Nepal.

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Respiratory symptoms and cross-shift lung function in relation to cotton dust and endotoxin exposure in textile workers in Nepal: a cross-sectional study

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