Published in final edited form as:
Occup Environ Med. 2009 March ; 66(3): 161–168. doi:10.1136/oem.2008.039065.

Dust and Chemical Exposures, and Miscarriage Risk Among Women Textile Workers in Shanghai, China

Eva Y. Wong, **Roberta M. Ray**, **Dao Li Gao**, **Karen J. Wernli**, **W Li**, **E. Dawn Fitzgibbons**, **Janice E. Camp**, **George Astrakianakis**, **Patrick J. Heagerty**, **David B. Thomas**, and **Harvey Checkoway**

EY Wong, KJ Wernli, W Li, DB Thomas, H Checkoway, Department of Epidemiology, School of Public Health and Community Medicine, University of Washington, Seattle, Washington, USA

R Ray, W Li, ED Fitzgibbons, DB Thomas, H Checkoway, Program in Epidemiology, Fred Hutchinson Cancer Research Center, Seattle, Washington, USA

DL Gao, Department of Epidemiology, Zhong Shan Hospital Cancer Center, Shanghai, People's Republic of China

JE Camp, G Astrakianakis, H Checkoway, Department of Environmental and Occupational Health Sciences, School of Public Health and Community Medicine, University of Washington, Seattle, WA, USA

PJ Heagerty, Department of Biostatistics, School of Public Health and Community Medicine, University of Washington, Seattle, WA, USA

Abstract

Introduction—To investigate possible associations between miscarriage and occupational exposures in the Shanghai Textile Industry.

Methods—We conducted a retrospective cohort study of miscarriages among 1,752 women in the Shanghai textile industry. Reproductive history was self-reported by women and occupational work histories were collected from factory personnel records. Occupational exposures were assigned by linking work history information to an industry-specific job-exposure matrix informed by factory-specific textile process information and industrial hygiene assessments. Estimates of cotton dust and endotoxin exposure were also assigned. Odds ratios (OR) and 95% confidence intervals (CI) were estimated by multivariate logistic regression, with adjustment for age at pregnancy, education level, smoking status of woman and spouse, use of alcohol, and woman's year of birth.

Results—An elevation in risk of a spontaneously aborted first pregnancy was associated with exposure to synthetic fibers (1.89, 95% CI: 1.20–3.00) and mixed synthetic and natural fibers (3.31, 95% CI: 1.30–8.42). No increased risks were observed for women working with solvents, nor were significant associations observed with quantitative cotton dust or endotoxin exposures. Associations were robust and similar when all pregnancies in a woman's reproductive history were considered.

Conclusions—Occupational exposure to synthetic fibers may cause miscarriages, and this possibility should be the subject of further investigation.

Correspondence to: H. Checkoway, Department of Environmental and Occupational Health Sciences, School of Public Health and Community Medicine, University of Washington, Box 357234, Seattle, Washington 98195-7234, USA, checko@u.washington.edu, Tel. 1-206-543-2052, Fax: 1-206 685-3990.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Keywords

Textile industry; endotoxin; cotton dust; solvents; synthetic fiber; miscarriage

INTRODUCTION

As an increasing number of women work outside the home during pregnancy, the role of occupational risk factors in adverse pregnancy and birth outcomes is of increasing importance. Work in the textile industry subjects employees to an array of exposures during the spinning, dyeing, weaving, sewing, and finishing of garments. In a study from Finland [1], textile spinning was associated with an increased risk of miscarriage (odds ratio [OR]=1.3, 95% confidence interval [CI]: 1.0–1.9), as has weaving (OR=1.4, 95% CI: 1.1–1.9), fabric inspection (OR=1.5, 95% CI: 1.0–2.4), and other textile work (OR=1.4, 95% CI: 1.0–2.0). In a separate Finnish study, women working at a textile plant had an increased rate of miscarriage (miscarriage rates of 16.7% vs. 11.4%) [2], but no significant increase in risk was found in a U.S. study of maternal occupation in the textile industry overall [3].

Textile workers may be exposed to cotton dust during fiber processing and spinning, solvents in the dyeing, weaving, and finishing of textile goods, and to bleaches and dyes during dyeing and weaving processes. Elevated miscarriage risks have been found in several occupational groups of women exposed to solvents, including factory workers (toluene) [4], semiconductor industry workers (glycol ethers) [5], and laboratory workers (toluene and xylene) [6]. Carbon disulfide is used in the manufacture of viscose rayon fibers in the textile industry, and increased miscarriage risk has been identified for women viscose rayon workers [7, 8]. Fiber dust exposure is widespread in the textile industry, with frequent exposure to cotton dust in the Shanghai, China textile industry. Cotton textile workers are commonly exposed to endotoxin, a lipopolysaccharide (LPS) component of the cell wall of gram-negative bacteria present in these and other organic dusts. Endotoxin is an established respiratory toxicant, and has been shown to induce miscarriage in animal studies [9–12]. Chemical and dust exposures of textile workers also are present in other industries; thus, findings from this study could have implications for exposures in other occupational settings.

A prior study of cancer risks in the Shanghai, China textile industry provided the opportunity to conduct a historical cohort study to examine associations between occupational exposures and self-reported history of miscarriage in a group of women textile workers.

METHODS

Study population

Study subjects for the current study were selected from participants previously enrolled in a large randomized trial (n=267,400) of breast self-examination conducted among workers from 526 factories affiliated with the Shanghai Textile Industry Bureau (STIB) in Shanghai, China. Enrollment in the trial occurred during 1988–91 [13, 14]. Women eligible for the randomized trial were Shanghai residents, born between 1925 and 1958 (aged 30–64 at entry into the study), who were current or retired workers in any of the factories. Participation in the study was high, with 98% of eligible women taking part in the study.

As part of two case-control studies of breast diseases nested within the randomized trial, 1814 control women (women without a diagnosis of breast cancer or benign breast disease in 1994) were administered a questionnaire that inquired about the woman's pregnancy history [15–17]. These women form the cohort of women for the current study. This reproductive questionnaire elicited detailed information for each pregnancy, including end date of pregnancy, outcome of each pregnancy, and length of gestation via in-person interview by trained Chinese physicians and nurses. Also recorded was information on personal and spousal smoking, alcohol use habits, demographic data, and gynecologic history (age at menarche, contraceptive use). The overall response rate was 81%. All procedures were approved by the relevant Institutional Review Boards of the Fred Hutchinson Cancer Research Center (Seattle, USA) and the Shanghai Textile Industry Bureau (Shanghai, China).

Outcome ascertainment

Among women who answered a detailed reproductive health questionnaire, 1752 (96.5%) had ever been pregnant and were included in the present study. The pregnancies as reported on the questionnaire occurred between 1942 and 2001. Most (92.6%) first pregnancies occurred between 1950 and 1989, and only 24 (1.4%) first pregnancies occurred between 1990 and 1996. A woman was considered to have had a miscarriage as a pregnancy outcome if she reported a miscarriage of less than 20 weeks gestation. Live births, termination of pregnancy (induced abortions), still births, and ectopic pregnancies were also reported pregnancy outcomes.

Exposure assessment

The STIB was an industry-wide governing body for all textile factories in Shanghai. Work in the factories included all textile processes from processing raw materials to completing the finished products. The STIB also employed women in jobs such as teaching, nursing and medical clinic work, cafeteria work, and daycare, resulting in a wide spectrum of occupational exposures.

Exposures for each woman were determined by collecting information on her work history and job assignments. Each woman's data on work history and job assignments were abstracted in 2005–2006 from factory personnel records using a standardized form and protocol by trained personnel who were all former medical workers employed at STIB factories. The factory in which a woman worked, the textile processes and fibers with which she worked, job tasks of the woman, and the dates of employment were collected beginning with the woman's first job until her last STIB job. For 89% of the job assignments held by the women, information was ascertained from factory records. In cases where factory personnel records could not be identified, supervisors were identified and completed the form (2.6 % of job assignments), or the woman was contacted and interviewed (7.3 % of job assignments).

Factory-level information was collected for each of the textile factories in the STIB using a standardized form. The data collection instrument was modeled after the exposure measurement forms routinely collected by the Shanghai Municipal Centers for Disease Control, district offices, or STIB industrial hygienists as part of their routine monitoring. Experienced industrial hygienists, trained in China, collected information from factories regarding factory demographics (date operation began, factory size currently and at peak, and fiber used in production) and a figure describing the factory process. The industrial hygienists also recorded every industrial workshop and process within the factory, excluding administrative and educational services. Within each textile process, the industrial hygienists detailed dates of operation, fiber, worker types, exposure to up to 5 hazardous agents, and any changes in the process (e.g., introducing synthetic fiber into a cotton factory). The industrial hygienists assessed hazardous exposure based on their experience, monitoring data, and investigations by the STIB. Textile processes were classified using a combination of 18 major process codes, which usually represented the workshop name (e.g., material handling, fiber processing, spinning, dyeing), and 149 specific process codes which identified one component of textile manufacturing within the major process (e.g., carding, drawing, combing, roving). A list of potentially hazardous exposures within each textile process was also recorded by the industrial hygienists and included 14 dusts (e.g., cotton, wool, synthetic fibers) and 239 chemicals (e.g., ammonia, formaldehyde, xylene). Infrequent exposures (<2 exposed women) are not presented in the tables.

A job-exposure matrix (JEM) specific to the textile industry was developed using a combination of information recorded by the Shanghai industrial hygienists and *a priori* assessment by a team of experts from the University of Washington and the STIB [18]. Exposure was assigned if the experts agreed that workers in the process would be exposed during normal operation, or if more than 30% of the textile processes reviewed above reported exposure on the standardized factory data collection forms [18]. Woman-level information and factory-level information were then linked by fiber type, major textile process type, specific textile process type, type of work performed (e.g. operator, floor supervisor), and year. Exposure to potentially hazardous agents was determined by linkage to the JEM. Further extensive details on exposure assessment, factory data collection and job-exposure matrix development are detailed in Wernli et al [18].

Quantitative exposure information was also available to determine cotton dust and endotoxin exposures. For cotton dust, historical industrial hygiene records from 56 factories between 1975 and 1999 were transcribed for use in this study to estimate exposure for each specific textile process. Endotoxin data for this industry from a study of respiratory health in three cotton products factories by Christiani et al. [19–21] and additional contemporary measurements of cotton dusts collected for this study [22, 23] were used in the development of predictive models for endotoxin exposure. For cotton dust and endotoxin, both exposures during the pregnancy alone and cumulative exposures from the beginning of her textile employment were of interest. Quantitative cotton dust and endotoxin estimates were combined with each woman's job-duration information from the work history to determine cumulative exposures.

Only work periods in STIB factories were included as the extensive exposure characterization was conducted solely for STIB factories. Three hundred twenty-three women were excluded from the analyses because their work history during their pregnancies could not be ascertained, leaving 1429 women included in the analyses.

Statistical analysis

For this historical cohort, quantitative analyses were first conducted evaluating associations between established risk factors (e.g., age at pregnancy, smoking status, and educational attainment), and pregnancy outcome to allow comparison with other epidemiologic studies. Then, analyses were conducted examining associations between pregnancy outcome(s) and textile industry exposures. Two separate analyses were conducted, the first utilizing all pregnancies, and the second using only each woman's first pregnancy. Analyses limited to the first pregnancy only were conducted to exclude biases from a woman's pregnancy history, including prior adverse outcomes and within-woman correlations among pregnancies, while avoiding bias associated with choosing the most recent pregnancy [24]. The most meaningful result to present from our data was a summary measure of the average risk ratio, hence the use of logistic regression analysis methods. In most analyses, we considered exposure only during pregnancy ("current exposure") to evaluate the effects of acute exposures during pregnancy. A woman was considered to have current exposure during the pregnancy if she was exposed between the estimated date of conception and the earlier of either her 20th week of pregnancy or the end date of the pregnancy. Prior mechanistic data supported a model of chronic exposure [25–28] potentially leading to miscarriage for endotoxin, thus cumulative exposure up to the first pregnancy was also analyzed for cotton dust and endotoxin exposure. Cumulative occupational exposure was accumulated from the beginning of a woman's first employment in the STIB up until the earlier of either the 20th week of the pregnancy or the end date of the pregnancy, excluding periods of nonexposure if the woman changed jobs. Analyses were conducted evaluating associations with specific potentially hazardous agents of interest as assigned using the JEM and with employment in a textile manufacturing process as a surrogate of potential exposure. Quantitative cotton dust and endotoxin exposures were analyzed by quartile of exposure among exposed women.

Analyses considering all pregnancies in a woman's reproductive history were conducted. In order to consider the within-woman correlations between pregnancies, analyses considering all pregnancies utilized generalized estimating equations (GEE) to estimate the odds ratio (OR) and 95% confidence interval(CI) [29]. Terminated pregnancy (induced abortions, n=1122), ectopic pregnancy (n=22), or other unspecified outcomes (n=4) were excluded. Our analyses thus compare pregnancies that end in miscarriage with the comparison group of pregnancies that could have ended in miscarriages, still births and live births. Analyses were adjusted for gravidity, age at pregnancy (in 5-year age groups), woman's year of birth, highest level of education completed (never went, elementary school, middle and high school, college or more), woman's smoking status during pregnancy (yes/no), spouse's smoking status during the pregnancy (yes/no), and woman's alcohol use (never, ≤1/month, ≤1/week, >1/week).

For secondary analyses considering the first pregnancy only, women whose first pregnancy resulted in a termination of pregnancy (n=46) or other pregnancy outcome (ectopic pregnancy (n=5) and other unspecified outcome (n=3)) were excluded from the comparison group. Analyses examining the outcome of the first pregnancy were conducted using logistic regression to estimate the odds ratio (OR) and 95% confidence interval (CI). As before, all analyses were adjusted for age at pregnancy, woman's year of birth, level of education, smoking status of the woman and the spouse, and alcohol use. All analyses were conducted in STATA version 9.0 (Stata Corporation, College Station, Texas).

RESULTS

There were a total of 4258 pregnancies experienced by the 1429 women in the study. Table 1 shows the numbers of pregnancies contributed by the women. Women had a median of 2 pregnancies, ranging from 1 to 10 pregnancies per woman. Approximately six percent of first pregnancies were miscarriages, with an additional 0.9% still birth, 0.4% ectopic pregnancy, and 89.4% live births. An additional 3.2% of first pregnancies were terminations of pregnancy. When considering all pregnancies, 4.4% were miscarriages and 59% were live births, but a much higher percent of pregnancy outcomes were terminations of pregnancy. The gestational durations differed by outcome of pregnancy, with live births having a mean of 40 weeks, miscarriage with a mean of 10.1 weeks, and termination of pregnancy occurred at a mean of 6.7 gestational weeks.

The distribution of the study subjects by age at first pregnancy is shown in table 2. Women whose first pregnancy occurred in their 20's represented 79% of the women in the study, and only 2% of women had a first pregnancy at age 35 years or later. Table 2 also shows that 76% of the women completed at least a middle school education (completed 8 years of education), all women had been married, smoking was infrequent (but spousal smoking was much more frequent), and alcohol use was also infrequent. Risk of a miscarriage was increased in teen pregnancies, and in women who smoked, and was lower than expected in women married to smokers. Women were more likely to have been born after the second world war, with 53% born between 1950 and 1958.

No statistically significant associations between miscarriages and employment in a specific textile process during pregnancy were identified when considering all pregnancies or when analyses were restricted to the first pregnancy (table 3).

An increased risk of miscarriages was found for women with exposure to synthetic fibers and mixed synthetic and natural fibers, both when analyses were limited to the first pregnancy, and when all pregnancies were considered (table 4). Among those few women who were exposed to synthetic or a mixture of natural and synthetic fibers, but not during their pregnancies, no elevation in risk was observed (for synthetic fibers, n=3 cases, OR=1.16, 95% CI: 0.35–3.88; and for mixed synthetic and natural fibers, n=1 case, OR=0.90, 95% CI: 0.12–6.97). Results for synthetic fiber exposures for first or all pregnancies were not appreciably changed when adjustments were made for exposures to other fiber types (OR=1.93, 95% CI: 1.21–3.08).

No statistically significant elevations in risk were found for women exposed to solvents, or any of the other exposures considered. No statistically significant elevations in risk of a miscarriage were observed with any of the measures of exposure to endotoxin or cotton dust that were utilized (Table 5).

DISCUSSION

An elevated risk of miscarriage was found in women with exposure to synthetic fibers and a mix of synthetic and natural fibers. No elevations in risk were identified with exposure to cotton dust, endotoxin, or solvents.

Synthetics fibers used in the Shanghai textile industry to which the women were exposed include polyester, lastrile, nylon, and rayon. The specific hazardous agents potentially responsible for the observed associations with synthetic fiber exposures are not known. Carbon disulfide, a major ingredient in rayon manufacturing, has been previously found to have reproductive effects in female viscose rayon workers [7, 8, 30]. Although carbon disulfide has been detected in historical measurement data in this industry, all measurements were conducted in synthetic fiber manufacturing factories, and no women in the current study were employed during pregnancy in factories manufacturing synthetic fibers. Only fifteen out of all five hundred STIB factories produced synthetic fibers and men may have been preferentially employed in manufacturing processes. Women working in manufacturing processes were not preferentially selected for inclusion in this study. In this study, women with exposure to synthetic fiber dusts encountered these dusts in non-manufacturing factories which used synthetic fibers to make finished products, and carbon disulfide exposure would not be expected in these processes. Textile processes associated with synthetic fiber dust exposure outside of manufacturing included applying coatings, spooling, weaving, knitting, printing, laminating, cutting, sewing, and packing of synthetic fiber products. It is also possible that the elevated risks associated with synthetic fiber exposure are surrogates of an exposure we were not able to fully characterize using our semi-quantitative job-exposure matrices.

Exposure to other solvents has also been associated with elevations in risk of a miscarriage. In a cohort of 3,105 non-smoking, 20 to 24 year old, female petrochemical workers in Beijing, the relative risk of a first pregnancy ending in a miscarriage was 2.7 (95% CI: 1.8–3.9) for exposure to any petrochemical and 2.5 (95% CI: 1.7–3.7) for exposure to benzene [31]. In a population based cohort of 15 to 29 year old pregnant women in the San Jose, CA area, elevated risks of miscarriage were found in relation to self reported jobs likely involving solvent exposures (OR=4.4, 95% CI: 1.5–12.7) and self-reported solvent exposures (OR=2.8, 95% CI: 1.1–7.0) [32]. In this study, women classified as having exposure to solvents were likely exposed to a mixture of solvents, and we were not able to identify exposures to specific solvents. No elevation in risk with exposure to solvents as a class was found. In the Shanghai textile industry, commonly used solvents included carbon disulfide, toluene, benzene, and xylene. Although historical industrial hygiene data were available, inconsistent data quality and lack of consistent monitoring did not allow for a quantitative job-exposure matrix of solvent exposure.

In the textile industry, exposure to cotton and other dusts is widespread, and exposures occur at exceptionally high levels in certain processes. Endotoxin is a lipopolysaccharide (LPS) component of the cell wall of gram-negative bacteria and is commonly found in cotton dusts. In animal studies, injections of endotoxin have led to miscarriages [9–11, 33], possibly as a result of a systemic inflammatory response which has been fairly consistently documented between studies and has been observed following either injection or inhalation exposure routes [34]. Occupational exposure to dusts has been previously associated with reproductive effects [1, 35]. Self-reported exposure to dusts was associated with a 2.7 (95% CI: 1.2–6.1) fold increase in risk of infertility, specifically ovulatory causes (3.0, 95% CI: 1.2–7.5) and tubal causes (2.9, 95% CI: 1.1–7.9) [35]. In contrast, another epidemiologic study found no association when using job titles to identify dust exposure (OR=1.1, 95% CI: 0.9–1.2) [1]. A strength of our current study was the ability to test the association of miscarriage with quantitative measurements of cotton dust and endotoxin exposure [23]. However, no significant elevations in risk of miscarriages with either endotoxin or cotton dust exposure were identified in the current study when examining the outcome of all pregnancies, when assessing cumulative exposures, or with concurrent exposure during the first pregnancy.

This study has several limitations that should be acknowledged. One is the potential for exposure misclassification that may have reduced our ability to detect true associations with miscarriage. Exposures were assigned based on linking employment history with a job-exposure matrix which was based on fiber type, major textile process type, specific process type, type of work, and year. The JEM was supplemented by historical industrial hygiene monitoring data, some of which did not span full years of the cohort's employment and were sparse in other years. The cotton dust and endotoxin data were based on considerably larger numbers of quantitative samples than were available for other agents.

Another potential limitation is the accuracy of pregnancy outcome data. All pregnancy outcomes of women in this study were determined via self-report a mean of 26 years (range 3–55 years) after occurrence. Self-reported miscarriages have been shown to be imperfectly recalled and the recall accuracy to decrease with time [36]. However, in this study [36], recall of miscarriages was over 80% within 10 years of the event, and 72% even after 30 years. Recall in our study may have decreased with time. Although validation of miscarriage is not possible with our available data, comparisons can be made to live births, which are likely recalled with a high degree of accuracy. The percent of first pregnancies ending in miscarriage remained between 6.0–7.7% for 3–29 years of recall decreasing to 5% between 30–49 years of recall. However, 11.5% of first pregnancies were miscarriages after 50 years of recall. Sociocultural factors in this population and time period supporting accurate recall of reproductive history include rates of miscarriage in this study similar to those in another textile industry population of women in China that utilized daily biomarkers to identify pregnancies and losses [37] although our rates of miscarriage are lower due to lack of biomarker pregnancy identification; under the one-child family planning policy and prior family planning policies, pregnancy occurrence was closely monitored and therefore care-seeking patterns did not play a role in the identification of pregnancies or pregnancy loss; and because all women in the study had routine access to medical care within their factory [38], inadequate access to care is not a likely factor leading to under-reporting of pregnancy outcomes. Furthermore, it is unlikely that any under-reporting of outcome of pregnancy would be related to any of the occupational exposures of interest, so any effect of under ascertainment of miscarriage would only obscure true associations, but would not lead to false relationships. It is possible that higher industrial exposures and more frequent underreporting of miscarriage may have occurred in the earlier study period years. Exposures were not found to vary significantly by decade of time, and thus time-dependent exposures were not included in the job-exposure matrices [18]. Underascertainment of miscarriage is possible due to the self-reported nature of these data. The current study found a miscarriage rate of 6% for the first pregnancy. A much lower miscarriage rate in subsequent pregnancies is due to the high rate of termination of pregnancy, in which some of those pregnancies would have gone on to become miscarriages. Although information on timing and dates was collected, self-reported pregnancy outcome data did not allow for a main analysis using a survival time approach. When sensitivity analyses were conducted using survival analysis techniques, no differences in conclusions were found.

High rates of termination of pregnancy were identified in this cohort of women. Termination of pregnancy is common among primiparous women, particularly after the implementation of family planning policies in 1979. Termination of pregnancy occurred at a mean of 6.7 gestational weeks, while miscarriage occurred at a mean of 10.1 weeks. The analysis considering all reproductive events may have some bias due to the high rates of termination of pregnancy in primiparous women. However the analyses considering the first pregnancy alone are not limited by this bias yet have similar conclusions, supporting the conclusions from our primary analyses considering all pregnancies.

Our results associated with spousal smoking are unexpected. Spousal (male) smoking status was determined retrospectively by asking the woman and thus may be under-reported. Study participants and their spouses were considered smokers if they had ever had more than 100 cigarettes in their lifetime. As expected, prevalence of spousal smoking is lowest for the earlier study years and increased over time.

Women in this current study were control subjects from prior nested case-control studies of breast disease within the larger cohort of 267,400 women textile workers. The response rates for both this study and the parent study were high, reducing the potential for biased participation by infertility status. The high participation rate was due to the extensive partnership with the textile industry thus allowing the researchers access to women and records, cultural norms supporting participation, and hiring of retired nurses and physician assistants who formerly worked in these factories as study recruiters. These control subjects completed a detailed reproductive history questionnaire for each pregnancy; this level of detail was not available on the baseline questionnaire for all randomized trial participants. However, using available information from the baseline questionnaire on outcome of the first pregnancy and total number of miscarriage experienced, no increased risk of breast cancer was identified with miscarriage history among these 267,400 women (OR 1.08, 95% CI: 0.87–1.34) compared to women who never had a miscarriage, nor was a trend with increasing number of miscarriages identified (p=0.90) [17]. Thus bias in the results examining associations between miscarriage outcome and textile industry exposures due to the selection method of this cohort is not expected.

This study also had some notable strengths, including availability of detailed reproductive history data for each woman and complete work history data in the textile industry, and data on potential confounders. Exposures were assigned by using written STIB personnel records for each woman, and very little misclassification is expected to have occurred because work history was found in STIB factories for 99% of women. Women also tended to be stable in a job position, with 19% of women ever holding only one job and 86% holding three or fewer jobs over her entire career. Confidence in the validity of the observed elevated risks in relation to synthetic fibers is enhanced by the lack of an elevated risk in women exposed to the same substances only while not pregnant. Use of personal protective equipment has also been uncommon historically, thus personal exposures did not vary significantly from the process area sampling used to inform the job-exposure matrices.

One of the most important features of this group of women is the virtual lack of potential bias due to more fertile workers preferentially leaving the workplace (infertile worker bias). Because of the government's universal employment policy, all pregnant women worked until shortly before the due date, then returned to the same job position after maternity leave. Thus, the cohort enabled analyses of workplace exposures and miscarriage risks free of potential biases in most other occupational settings.

This study of occupational miscarriage risks in the textile industry identified elevations in risk with exposure to synthetic fibers and a mix of synthetic and natural fibers. This study offered an opportunity to study exposures that are relatively widespread worldwide and which occur with particularly high frequency and intensity in this industry. In conjunction with extensive health and exposure information, this study was able to quantitatively evaluate associations between miscarriage and occupational exposures and enable inference to other occupationally-exposed women. Specific causative agents were not readily identifiable, and should be the subject of additional studies.

MAIN MESSAGES

- Among a group of women working in the textile industry who had low rates of alcohol use and smoking, elevations in risk of miscarriage were identified for women whose jobs entailed exposure to synthetic fibers and a mixture of synthetic and natural fibers.
- No elevations in miscarriage risk were identified for women textile workers whose jobs included exposure to cotton dust, or endotoxin.
- Exposure levels of solvents experienced by women in the textile industry do not appear to be associated with risk of miscarriage.

POLICY IMPLICATIONS

- Occupational exposures in the textile industry may increase risk of miscarriages. Other occupationally-exposed women may also experience these risks.
- Exposure to synthetic fibers may increase risk of miscarriages. This possibility needs to be corroborated by independent investigations, and the specific agents in synthetic fibers that may be responsible for these possible elevations in risk need to be identified.

Acknowledgments

This research was supported by the grant R01 CA80180 from the US National Cancer Institute, R01OH008149 from the US National Institute for Occupational Safety and Health, and by the training grant T32ES07262 from the US National Institute of Environmental Health Sciences. The authors would like to thank Drs. Fan Liang Chen, Yong Wei Hu, Guan Lin Zhao, and Lei Da Pan for their ongoing support. The authors thank Wen Wan Wang for project management; Drs. He Lian Dai, Zhu Ming Wang, A Zhen Qi, Zia Ming Wang, Wei Ping Xiang, and Yu Fang Li for their diligence in collection of factory information; the 30 field workers for the collection of women's personnel records; and Georgia Green, Shirley Zhang, Richard Gandolfo, and Ted Grichuhin for technical and administrative support.

References

1. Lindbohm ML, Hemminki K, Kyyronen P. Parental occupational exposure and spontaneous abortions in Finland. Am J Epidemiol 1984;120(3):370–8. [PubMed: 6475914]
2. Hemminki K, Kyyronen P, Niemi ML, Koskinen K, Sallmen M, Vainio H. Spontaneous abortions in an industrialized community in Finland. Am J Public Health 1983;73(1):32–7. [PubMed: 6847997]
3. Savitz DA, Brett KM, Baird NJ, Tse CK. Male and female employment in the textile industry in relation to miscarriage and preterm delivery. Am J Ind Med 1996;30(3):307–16. [PubMed: 8876799]
4. Ng TP, Foo SC, Yoong T. Risk of spontaneous abortion in workers exposed to toluene. Br J Ind Med 1992;49(11):804–8. [PubMed: 1463682]
5. Swan SH, Beaumont JJ, Hammond SK, VonBehren J, Green RS, Hallock MF, et al. Historical cohort study of spontaneous abortion among fabrication workers in the Semiconductor Health Study: agent-level analysis. Am J Ind Med 1995;28(6):751–69. [PubMed: 8588562]
6. Taskinen H, Kyyronen P, Hemminki K, Hoikkala M, Lajunen K, Lindbohm ML. Laboratory work and pregnancy outcome. J Occup Med 1994;36(3):311–9. [PubMed: 8195901]

7. Hemminki K, Franssila E, Vainio H. Spontaneous abortions among female chemical workers in Finland. Int Arch Occup Environ Health 1980;45(2):123–6. [PubMed: 7364488]
8. Hemminki K, Niemi ML. Community study of spontaneous abortions: relation to occupation and air pollution by sulfur dioxide, hydrogen sulfide, and carbon disulfide. Int Arch Occup Environ Health 1982;51(1):55–63. [PubMed: 7152702]
9. Foley GL, Schlafer DH. Bacterial endotoxemia and reproductive effects in ruminants. Vet Clin North Am Food Anim Pract 1994;10(3):491–501. [PubMed: 7728632]
10. Gasic GJ, Gasic TB, Strauss JF. Abortifacient effects of Vibrio cholerae exo-enterotoxin and endotoxin in mice. J Reprod Fertil 1975;45(2):315–22. [PubMed: 1206628]
11. Wrathall AE, Wray C, Bailey J, Wells DE. Experimentally induced bacterial endotoxaemia and abortion in pigs. Br Vet J 1978;134(3):225–30. [PubMed: 352477]
12. Wang YY, Tawfik O, Wood GW. Endotoxin-induced abortion in mice is mediated by activated fetal macrophages. J Leukoc Biol 1998;63(1):40–50. [PubMed: 9469471]
13. Thomas DB, Gao DL, Ray RM, Wang WW, Allison CJ, Chen FL, et al. Randomized trial of breast self-examination in Shanghai: final results. J Natl Cancer Inst 2002;94(19):1445–57. [PubMed: 12359854]
14. Thomas DB, Gao DL, Self SG, Allison CJ, Tao Y, Mahloch J, et al. Randomized trial of breast self-examination in Shanghai: methodology and preliminary results. J Natl Cancer Inst 1997;89(5):355–65. [PubMed: 9060957]
15. Li W, Ray RM, Lampe JW, Lin MG, Gao DL, Wu C, et al. Dietary and other risk factors in women having fibrocystic breast conditions with and without concurrent breast cancer: a nested case-control study in Shanghai, China. Int J Cancer 2005;115(6):981–93. [PubMed: 15723298]
16. Shannon J, Ray R, Wu C, Nelson Z, Gao DL, Li W, et al. Food and botanical groupings and risk of breast cancer: a case-control study in Shanghai, China. Cancer Epidemiol Biomarkers Prev 2005;14 (1):81–90. [PubMed: 15668480]
17. Ye Z, Gao DL, Qin Q, Ray RM, Thomas DB. Breast cancer in relation to induced abortions in a cohort of Chinese women. Br J Cancer 2002;87(9):977–81. [PubMed: 12434288]
18. Wernli KJ, Astrakianakis G, Camp JE, Ray RM, Chang CK, Li GD, et al. Development of a job exposure matrix (JEM) for the textile industry in Shanghai, China. J Occup Environ Hyg 2006;3(10): 521–9. [PubMed: 16908453]
19. Olenchock SA, Christiani DC, Mull JC, Ye TT, Lu PL. Airborne endotoxin concentrations in various work areas within two cotton textile mills in the People's Republic of China. Biomed Environ Sci 1990;3(4):443–51. [PubMed: 2096849]
20. Christiani DC, Wegman DH, Eisen EA, Ye TT, Lu PL, Olenchock SA. Cotton dust and gram-negative bacterial endotoxin correlations in two cotton textile mills. Am J Ind Med 1993;23(2):333–42. [PubMed: 8427261]
21. Christiani DC, Ye TT, Zhang S, Wegman DH, Eisen EA, Ryan LA, et al. Cotton dust and endotoxin exposure and long-term decline in lung function: results of a longitudinal study. Am J Ind Med 1999;35(4):321–31. [PubMed: 10086207]
22. Astrakianakis G, Seixas N, Camp J, Smith TJ, Bartlett K, Checkoway H. Cotton dust and endotoxin levels in three Shanghai textile factories: a comparison of samplers. J Occup Environ Hyg 2006;3 (8):418–27. [PubMed: 16862712]
23. Astrakianakis G, Seixas NS, Camp JE, Christiani DC, Feng Z, Thomas DB, et al. Modeling, estimation and validation of cotton dust and endotoxin exposures in Chinese textile operations. Ann Occup Hyg 2006;50(6):573–82. [PubMed: 16632488]
24. Weinberg CR, Baird DD, Wilcox AJ. Bias in retrospective studies of spontaneous abortion based on the outcome of the most recent pregnancy. Ann N Y Acad Sci 1994;709:280–6. [PubMed: 8154720]
25. Michel O, Ginanni R, Le Bon B, Content J, Duchateau J, Sergysels R. Inflammatory response to acute inhalation of endotoxin in asthmatic patients. Am Rev Respir Dis 1992;146(2):352–7. [PubMed: 1489124]
26. Michel O, Nagy AM, Schroeven M, Duchateau J, Neve J, Fondu P, et al. Dose-response relationship to inhaled endotoxin in normal subjects. Am J Respir Crit Care Med 1997;156(4 Pt 1):1157–64. [PubMed: 9351616]

27. Hoffmann HJ, Iversen M, Brandslund I, Sigsgaard T, Omland O, Oxvig C, et al. Plasma C3d levels of young farmers correlate with respirable dust exposure levels during normal work in swine confinement buildings. Ann Agric Environ Med 2003;10(1):53–60. [PubMed: 12852733]

28. Jagielo PJ, Thorne PS, Watt JL, Frees KL, Quinn TJ, Schwartz DA. Grain dust and endotoxin inhalation challenges produce similar inflammatory responses in normal subjects. Chest 1996;110 (1):263–70. [PubMed: 8681637]

29. Diggle, PJ.; Heagerty, P.; Liang, K-Y.; Zeger, SL. Analysis of Longitudinal Data. 2. New York: Oxford University Press, Inc; 2002.

30. Zhou SY, Liang YX, Chen ZQ, Wang YL. Effects of occupational exposure to low-level carbon disulfide (CS2) on menstruation and pregnancy. Ind Health 1988;26(4):203–14. [PubMed: 3230053]

31. Xu X, Cho SI, Sammel M, You L, Cui S, Huang Y, et al. Association of petrochemical exposure with spontaneous abortion. Occup Environ Med 1998;55(1):31–6. [PubMed: 9536160]

32. Lipscomb JA, Fenster L, Wrensch M, Shusterman D, Swan S. Pregnancy outcomes in women potentially exposed to occupational solvents and women working in the electronics industry. J Occup Med 1991;33(5):597–604. [PubMed: 1870012]

33. Janosi S, Huszenicza G, Kulcsar M, Korodi P. Endocrine and reproductive consequences of certain endotoxin-mediated diseases in farm mammals: a review. Acta Vet Hung 1998;46(1):71–84. [PubMed: 9704512]

34. Beishuizen A, Thijs LG. Endotoxin and the hypothalamo-pituitary-adrenal (HPA) axis. J Endotoxin Res 2003;9(1):3–24. [PubMed: 12691614]

35. Smith EM, Hammonds-Ehlers M, Clark MK, Kirchner HL, Fuortes L. Occupational exposures and risk of female infertility. J Occup Environ Med 1997;39(2):138–47. [PubMed: 9048320]

36. Wilcox AJ, Horney LF. Accuracy of spontaneous abortion recall. Am J Epidemiol 1984;120(5):727–33. [PubMed: 6541871]

37. Venners SA, Korrick S, Xu X, Chen C, Guang W, Huang A, et al. Preconception serum DDT and pregnancy loss: a prospective study using a biomarker of pregnancy. Am J Epidemiol 2005;162(8): 709–16. [PubMed: 16120699]

38. Camp JE, Seixas NS, Wernli K, Fitzgibbons D, Astrakianakis G, Thomas DB, et al. Development of a cancer research study in the Shanghai textile industry. Int J Occup Environ Health 2003;9(4):347–56. [PubMed: 14664489]

Table 1

Descriptive statistics of women and pregnancies.

	n
Women	1429
Total number of pregnancies	4258
Number of women contributing to each pregnancy number	
One	1,429
Two	1,192
Three	744
Four	454
Five or more	235
Number of pregnancies per woman	
1st quartile	1
Median	2
3rd quartile	3
Maximum number of pregnancies	10
Outcome of first pregnancy	**n (%)**
Live birth	1278 (89.4%)
Termination of pregnancy	46 (3.2%)
Miscarriage	84 (5.9%)
Still birth	13 (0.9%)
Ectopic pregnancy or other outcome	8 (0.6%)

Table 2

Demographic characteristics of women working in the Shanghai textile industry studied for risk of miscarriage, based on outcome of the first pregnancy.

	First Pregnancy Outcome					
	Miscarriage (N=84)		Other[a] (N=1291)			
	n	%	n	%	OR[b]	95% CI[b]
Age at first pregnancy						
15–19	5	6.0	41	3.2	3.23	(1.05–9.93)
20–24	16	19.0	287	22.2	1.00	(ref)
25–29	46	54.8	736	57.0	0.81	(0.40–1.61)
30–34	14	16.7	200	15.5	0.89	(0.39–2.08)
35+	3	3.6	27	2.1	1.35	(0.32–5.64)
Alcohol consumption						
Never	79	94.0	1164	90.2	1.00	(ref)
<=1/month	2	2.4	37	2.9	0.79	(0.18–3.38)
<=1/week	1	1.2	33	2.6	0.36	(0.05–2.83)
>1/week	2	2.4	55	4.3	0.49	(0.11–2.06)
Smoking Status During Pregnancy						
Did not smoke	82	97.6	1287	99.7	1.00	(ref)
Smoked	2	2.4	4	0.3	12.23	(1.87–79.76)
Spouse's Smoking Status During Pregnancy						
Did not smoke	63	75.0	770	59.6	1.00	(ref)
Smoked	21	25.0	521	40.4	0.40	(0.23–0.69)
Education Completed (Years Completed)						
None (<5 years)	6	7.1	131	10.1	1.00	(ref)
Elementary (5 years)	7	8.3	181	14.0	0.96	(0.30–3.00)
Middle School (8 years)	68	81.0	931	72.1	2.06	(0.65–6.51)
College or Over (11 or more)	3	3.6	48	3.7	1.58	(0.32–7.78)
Year First Pregnancy Ended						
1942–1949	5	6.0	41	3.2		
1950–1954	3	3.6	114	8.8		
1955–1959	7	8.3	126	9.8		
1960–1964	4	4.8	87	6.7		

	First Pregnancy Outcome					
	Miscarriage (N=84)		Other[a] (N=1291)			
	n	%	n	%	OR[b]	95% CI[b]
1965–1969	5	6.0	92	7.1		
1970–1974	6	7.1	78	6.0		
1975–1979	11	13.1	130	10.1		
1980–1984	29	34.5	396	30.7		
1985–1989	13	15.5	204	15.8		
1990–2002	1	1.2	23	1.8		
Woman's Year of Birth						
1925–1929	5	6.0	98	7.6		
1930–1934	10	11.9	181	14.0		
1935–1939	3	3.6	101	7.8		
1940–1944	8	9.5	67	5.2		
1945–1949	9	10.7	152	11.8		
1950–1954	24	28.6	240	18.6		
1955–1958	25	29.8	452	35.0		

[a]Other outcomes include still births and live births.

[b]OR, Odds Ratio; CI, confidence interval.

Table 3

Risk of miscarriage for those exposed (≥1 day) vs. not (<1 day) exposed during pregnancy by employment in textile process, adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth.

	First pregnancy only						All pregnancies					
	Other Outcome		Miscarriage		OR[a]	95% CI[a]	Other Outcome		Miscarriage		OR[a]	95% CI[a]
Exposure	**n**	**%**	**n**	**%**			**n**	**%**	**n**	**%**		
Total												
Warehouse/packing/quality control												
Unexposed	1169	93.6	80	6.4	1.00	(ref)	2584	93.6	178	6.4	1.00	(ref)
Exposed	122	96.8	4	3.2	0.43	(0.15–1.22)	242	94.2	15	5.8	0.82	(0.49–1.38)
Cotton fiber-material handling, fiber processing, spinning												
Unexposed	1122	93.7	76	6.3	1.00	(ref)	2425	93.7	164	6.3	1.00	(ref)
Exposed	169	95.5	8	4.5	0.70	(0.32–1.52)	401	93.3	29	6.7	1.20	(0.71–2.01)
Wool fiber-material handling, fiber processing, spinning												
Unexposed	1260	93.8	83	6.2	1.00	(ref)	2750	93.6	188	6.4	1.00	(ref)
Exposed	31	96.9	1	3.1	0.52	(0.07–3.90)	76	93.8	5	6.2	1.01	(0.42–2.47)
Synthetic fiber-material handling, fiber processing, spinning												
Unexposed	1266	93.9	82	6.1	1.00	(ref)	2773	93.6	189	6.4	1.00	(ref)
Exposed	25	92.6	2	7.4	0.98	(0.21–4.65)	53	93.0	4	7.0	0.97	(0.35–2.70)
Mixed fiber-material handling, fiber processing, spinning												
Unexposed	1142	93.9	74	6.1	1.00	(ref)	2476	93.7	167	6.3	1.00	(ref)
Exposed	149	93.7	10	6.3	1.12	(0.56–2.25)	350	93.1	26	6.9	1.18	(0.72–1.93)
Weaving												
Unexposed	925	94.2	57	5.8	1.00	(ref)	1923	93.3	137	6.65	1.00	(ref)
Exposed	366	93.1	27	6.9	1.32	(0.81–2.16)	903	94.2	56	5.84	1.00	(0.71–1.42)
Cutting/sewing												
Unexposed	1190	94.0	76	6.0	1.00	(ref)	2647	93.6	182	6.43	1.00	(ref)
Exposed	101	92.7	8	7.3	1.20	(0.55–2.62)	179	94.2	11	5.79	0.75	(0.39–1.43)
Administration/nonproduction												
Unexposed	1111	94.2	68	5.8	1.00	(ref)	2465	93.8	163	6.20	1.00	(ref)
Exposed	180	91.8	16	8.2	1.51	(0.82–2.79)	361	92.3	30	7.67	1.06	(0.68–1.66)
Other manufacturing												

Exposure	First pregnancy only						All pregnancies					
	Other Outcome		Miscarriage		OR[a]	95% CI[a]	Other Outcome		Miscarriage		OR[a]	95% CI[a]
	n	%	n	%			n	%	n	%		
Unexposed	1226	94.0	78	6.0	1.00	(ref)	2702	93.6	185	6.41	1.00	(ref)
Exposed	65	91.5	6	8.5	1.23	(0.51–2.97)	124	93.9	8	6.06	0.83	(0.39–1.78)

[a]OR, Odds Ratio; CI, confidence interval.

Table 4

Risk of miscarriage for those ever/never exposed during pregnancy to dusts and hazardous agents, adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth

	First pregnancy only						All pregnancies					
	Other Outcome		Miscarriage		OR[a]	95% CI[a]	Other Outcome		Miscarriage		OR[a]	95% CI[a]
Exposure	n	%	N	%			n	%	n	%		
Total												
Cotton dust												
Unexposed	596	93.6	41	6.4	1.00	(ref)	1220	93.3	88	6.7	1.00	(ref)
Exposed	695	94.2	43	5.8	0.98	(0.62–1.56)	1606	93.9	105	6.1	1.02	(0.74–1.40)
Wool dust												
Unexposed	1152	93.8	76	6.2	1.00	(ref)	2512	93.6	173	6.4	1.00	(ref)
Exposed	139	94.6	8	5.4	0.87	(0.40–1.87)	314	94.0	20	6.0	0.90	(0.53–1.55)
Silk dust												
Unexposed	1235	94.1	78	5.9	1.00	(ref)	2681	93.7	180	6.3	1.00	(ref)
Exposed	56	90.3	6	9.7	1.66	(0.67–4.08)	145	91.8	13	8.2	1.45	(0.70–3.00)
Synthetic fiber dust												
Unexposed	885	95.1	46	4.9	1.00	(ref)	1925	94.4	114	5.6	1.00	(ref)
Exposed	406	91.4	38	8.6	1.89	(1.20–3.00)	901	91.9	79	8.1	1.46	(1.07–1.99)
Mixed fiber, not otherwise specified (mix of synthetic/natural)												
Unexposed	1260	94.2	78	5.8	1.00	(ref)	2740	93.8	181	6.2	1.00	(ref)
Exposed	31	83.8	6	16.2	3.31	(1.30–8.42)	86	87.8	12	12.2	1.99	(0.95–4.18)
Solvents												
Unexposed	1127	93.6	77	6.4	1.00	(ref)	2516	93.4	177	6.6	1.00	(ref)
Exposed	164	95.9	7	4.1	0.54	(0.24–1.21)	310	95.1	16	4.9	0.63	(0.37–1.08)
Acids and bases												
Unexposed	1204	93.8	80	6.2	1.00	(ref)	2657	93.6	181	6.4	1.00	(ref)
Exposed	87	95.6	4	4.4	0.60	(0.21–1.71)	169	93.4	12	6.6	0.98	(0.46–2.08)
Resins												
Unexposed	1261	94.0	80	6.0	1.00	(ref)	2772	93.6	188	6.4	1.00	(ref)
Exposed	30	88.2	4	11.8	1.91	(0.64–5.68)	54	91.5	5	8.5	1.20	(0.44–3.31)
Lubricants												

NIH-PA Author Manuscript
NIH-PA Author Manuscript

	First pregnancy only						All pregnancies					
	Other Outcome		Miscarriage		OR[a]	95% CI[a]	Other Outcome		Miscarriage		OR[a]	95% CI[a]
Exposure	**n**	**%**	**N**	**%**			**n**	**%**	**n**	**%**		
Unexposed	595	93.0	45	7.0	1.00	(ref)	1182	92.6	94	7.4	1.00	(ref)
Exposed	696	94.7	39	5.3	0.78	(0.49–1.24)	1644	94.3	99	5.7	0.87	(0.62–1.22)
Metals												
Unexposed	1204	93.7	81	6.3	1.00	(ref)	2661	93.5	185	6.5	1.00	(ref)
Exposed	87	96.7	3	3.3	0.44	(0.13–1.45)	165	95.4	8	4.6	0.63	(0.32–1.25)

[a]OR, Age adjusted odds ratio; CI, confidence interval.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 5

Risk of miscarriage with exposure during the pregnancy only and cumulative exposure beginning from the start of employment, using quantitative cotton and endotoxin measurements. Exposure by quartiles, analyses adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth.

	Other Outcome		Miscarriage		OR[a]	95% CI[a]	p-trend
	N	%	n	%			
Exposure During First Pregnancy							
Endotoxin (EU/m^3 × years)[b]							
None	659	92.7	52	7.3	1.00	(ref)	0.46
0–65.0	235	95.5	11	4.5	0.62	(0.31–1.23)	
65.0–124	228	95.4	11	4.6	0.63	(0.32–1.25)	
124–253	221	90.6	23	9.4	1.57	(0.92–2.68)	
253 or more	232	95.1	12	4.9	0.79	(0.40–1.55)	
Cotton Dust (mg/m^3 × years)							
None	659	92.7	52	7.3	1.00	(ref)	0.73
0–2.26	194	94.2	12	5.8	0.81	(0.41–1.60)	
2.26–4.66	254	92.0	22	8.0	1.20	(0.71–2.05)	
4.66–8.88	232	95.5	11	4.5	0.68	(0.34–1.34)	
8.88 or more	236	95.2	12	4.8	0.74	(0.37–1.47)	
Exposure During All Pregnancies							
Endotoxin (EU/m^3 × years)[b]							
None	1387	93.5	96	6.5	1.00	(ref)	0.22
0–92.6	516	94.7	29	5.3	0.76	(0.47–1.24)	
92.6–169	453	91.5	42	8.5	1.37	(0.92–2.03)	
169–320	551	94.3	33	5.7	1.00	(0.62–1.61)	
320 or more	598	93.4	42	6.6	1.24	(0.81–1.92)	
Cotton Dust (mg/m^3 × years)							
None	1387	93.5	96	6.5	1.00	(ref)	0.09
0–3.37	505	94.0	32	6.0	0.85	(0.53–1.36)	
3.37–6.58	473	92.6	38	7.4	1.17	(0.77–1.78)	
6.58–11.85	535	94.4	32	5.6	0.97	(0.60–1.55)	
11.85 or more	605	93.2	44	6.8	1.36	(0.88–2.11)	

	Other Outcome		Miscarriage		OR[a]	95% CI[a]	p-trend
	N	**%**	**n**	**%**			
Cumulative Exposure for First Pregnancy							
Endotoxin (EU/m^3 × years)[b]							
None	792	93.3	57	6.7	1.00	(ref)	0.37
0–339	197	93.8	13	6.2	0.97	(0.52–1.83)	
339–630	199	95.2	10	4.8	0.72	(0.36–1.46)	
630–1087	196	93.8	13	6.2	1.04	(0.55–1.98)	
1087 or more	191	92.3	16	7.7	1.12	(0.60–2.09)	
Cotton Dust (mg/m^3 × years)							
None	792	93.3	57	6.7	1.00	(ref)	0.98
0–12.8	191	92.3	16	7.7	1.23	(0.69–2.21)	
12.8–24.6	197	94.7	11	5.3	0.83	(0.42–1.63)	
24.6–42.1	202	95.3	10	4.7	0.71	(0.35–1.43)	
42.1 or more	193	92.8	15	7.2	1.08	(0.57–2.05)	

[a]OR, Odds Ratio; CI, confidence interval.

[b]EU, endotoxin units