Physical Activity, Physical Exertion, and Miscarriage Risk in Women Textile Workers in Shanghai, China

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Background *Strenuous occupational physical activity and physical demands may be risk factors for adverse reproductive outcomes.*

Methods *A retrospective study in the Shanghai, China textile industry study collected women's self-reported reproductive history. Occupational physical activity assessment linked complete work history data to an industry-specific job-exposure matrix. Odds ratios (OR) and 95% confidence intervals (CI) were estimated by multivariate logistic regression for the first pregnancy outcome and utilized generalized estimating equations to consider all pregnancies per woman.*

Results *Compared with women employed in sedentary jobs, a reduced risk of miscarriage was found for women working in jobs with either light (OR 0.18, 95% CI: 0.07, 0.50) or medium (OR 0.24, 95% CI: 0.08, 0.66) physical activity during the first pregnancy and over all pregnancies (light OR 0.32, 95% CI: 0.17, 0.61; medium OR 0.43, 95% CI: 0.23, 0.80). Frequent crouching was associated with elevated risk (OR 1.82, 95% CI: 1.14, 2.93; all pregnancies per woman).*

Conclusions *Light/medium occupational physical activity may have reduced miscarriage risk, while specific occupational characteristics such as crouching may have increased risk in this cohort.* Am. J. Ind. Med. 53:497–505, 2010. *© 2010 Wiley-Liss, Inc.*

KEY WORDS: miscarriage; physical activity; occupation; reproductive; textile

INTRODUCTION

Women are encouraged to participate in regular, moderate exercise while pregnant [American College of Obstetricians and Gynecologists, 2002; American College of Obstetricians and Gynecologists, American Academy of Pediatrics, 2002]; however, increased and/or strenuous occupational physical activity has been associated with an elevated risk of miscarriage. Although this evidence has been mixed with some null studies [Axelsson et al., 1989; John et al., 1994; Fenster et al., 1997], associations have been observed related to heavy lifting [Taskinen et al., 1986, 1990; McDonald et al., 1988; El-Metwalli et al., 2001], standing for extended periods [McDonald et al., 1988; Eskenazi et al., 1994; Beaumont et al., 1995; Schenker et al., 1995; Swan

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et al., 1995], and bending [Florack et al., 1993; El-Metwalli et al., 2001]. In one occupational study, lifting heavy weights (15 or more times per day) was associated with a significant 1.5-fold increase in risk and other physical effort was associated with a significant 1.4-fold increase in risk of miscarriage [McDonald et al., 1988].

Prior evidence on the effects of occupational work on miscarriage risk is difficult to interpret as exposures have been variously defined and subject to misclassification. Studies have relied upon self-reported physical activity, even where industrial hygiene assessments were used to assign other exposures [McDonald et al., 1986]. Furthermore, physical activity has been variously defined by using either individual characteristics of a woman's occupation such as standing, stooping, or crouching [McDonald et al., 1986; Taskinen et al., 1986, 1990; Florack et al., 1993; Eskenazi et al., 1994; Fenster et al., 1997; El-Metwalli et al., 2001] or by use of study-specific exposure scales [Florack et al., 1993; El-Metwalli et al., 2001]. Study-specific definitions do not readily allow comparisons between studies and may additionally be difficult to generalize to other occupational groups or to recreational exposures.

High noise levels are also hypothesized to exert adverse reproductive effects, although as with physical activity, epidemiologic evidence has not been consistent. No increased risk of miscarriage was found for women working in the manufacturing sector [McDonald et al., 1986, 1988], although textile workers exposed to more than 85 decibels (dBA) were found to have significantly increased rates of miscarriage [Zhan et al., 1991]. The Shanghai textile industry includes the processing of raw materials to make finished products, for example, weaving and spinning, and also includes ancillary support staff such as daycare and cafeteria workers. Thus a wide range of noise exposures is experienced in this industry.

This article presents findings from a study of physical activity, physical demands, and noise exposure in relation to miscarriage risk among Shanghai, China women textile workers employed in a wide range of job duties. We hypothesized the physical activity, physical demand, and noise exposures of women Shanghai textile industry workers would be associated with miscarriage risk. By utilizing a semi-quantitative job-exposure matrix (JEM) in this study, results can be applied and compared to risk in other occupational settings.

MATERIALS AND METHODS

Population

All study subjects were participants in a large randomized trial of breast cancer (n = 267,400) conducted within the Shanghai textile industry [Thomas et al., 1997, 2002]. To be eligible for inclusion, women were Shanghai residents born between 1925 and 1958 (aged 30–64 at trial entry beginning in 1989) currently employed or a retiree associated with 1 of over 500 textile factories within the Shanghai Textile Industry Bureau (STIB), an industry-wide governing body. The randomized trial had a response rate of 98%.

As part of two case-control studies of breast cancer or benign breast disease nested within the trial cohort, 1,814 women (control women, without a diagnosis of breast cancer or benign breast disease in 1994) completed a detailed reproductive history questionnaire via in-person interview by trained former Chinese physicians and nurses (81% response rate) [Ye et al., 2002; Li et al., 2005; Shannon et al., 2005]. These 1,814 women form the cohort for the current study of miscarriage. Detailed questions about each pregnancy including pregnancy outcome (live birth, still birth, miscarriage, induced abortion, ectopic/tubal pregnancy), dates of gestation, and length of gestation were self-reported by each woman. Information regarding smoking and alcohol use habits, and demographic data was also elicited at both entry into the trial and on enrollment into the nested case-control studies. The current study population was restricted to women who had ever been pregnant (n = 1,752, 96.5%). Miscarriage was considered to be the pregnancy outcome if a woman reported a spontaneous fetal loss of less than 20 weeks gestation. All study procedures were approved by the Institutional Review Boards of the Fred Hutchinson Cancer Research Center (Seattle, USA) and the Shanghai Textile Industry Board (Shanghai, China).

Exposure Assessment

Physical activity exposures for each woman during her pregnancies were determined by linking information on each woman's work history and job assignments to a JEM developed specifically for the Shanghai textile industry. Exposures were assigned without knowledge of reproductive history. Using a standardized form, trained study personnel collected information on each woman's employment history from written STIB personnel records (89% of job assignments) or in-person interviews with subjects (7.3%) or supervisors (2.6%). If in-person interviews were necessary, oral consent was obtained. Abstracted employment data included dates of employment, factory, and sub-factory workshop areas of employment, textile processes in which the woman was employed, and her job tasks. Employment information was collected for all STIB jobs from the beginning of each woman's employment in the STIB.

Factory-level information on textile processes, sub-factory workshops, and factory demographic data were collected for each of the 503 STIB factories using a standardized methodology by trained Chinese industrial hygienists with extensive experience in the textile industry. Using a combination of 18 major process codes (for example, warehouse/packing, weaving, or cutting/sewing) and 149 specific process codes

which identified one component of textile manufacturing within the major process, all textile processes were uniquely identified [Wernli et al., 2006].

Using a combination of major and specific textile process codes, a semi-quantitative physical activity JEM was developed by matching each textile process to the job titles of the US Department of Labor Dictionary of Occupational Titles (DOT) [US Department of Labor, 1991]. Matching was independently conducted by two occupational epidemiologists (EYW, KJW) without consideration of physical activity assignment, and a consensus reached. If a consensus could not be reached or an appropriate job title could not be identified, the matching was determined by an experienced industrial hygienist (JEC). Physical activity characteristics were then assigned using the DOT-matched job classification. Job characteristics evaluated included overall physical activity (sedentary, light, medium, heavy, very heavy), physical exertion characteristics of each job (stooping, crouching, reaching, handling, exposure to weather, extreme heat, extreme cold, atmospheric conditions, climbing, balancing, kneeling, crawling, wet/dry conditions), and the noise intensity level of each job (very quiet, quiet, moderate, loud) (Table I). Physical activity as determined by the DOT was based on a combination of frequency of weight lifted, amount of weight lifted, and proportion of time spent standing or sitting to assign physical activity level (Table I). Woman-level and factory-level information were then linked by major textile process, specific textile process, and type of work performed (operator or supervisor). Major and specific processes were not found to vary significantly over time within the cohort [Wernli et al., 2006]. Infrequent exposures ($n < 3$ exposed women) are not presented.

Work history information could not be located for 10 women. For an additional 302 women work history information was collected, but place of employment during pregnancy could not be ascertained due to gaps in employment history; these women were excluded from further analyses. An additional 13 women who worked in silk manufacturing were excluded as the DOT does not contain silk-related processes. Thus, a total of 1,427 women were included in the analyses.

Statistical Analysis

Analyses within the cohort were conducted examining associations of physical activity, physical exertion, and noise exposures during pregnancy up to the 20th week of gestation. Only exposures during this pregnancy period were considered. Physical activity and the noise intensity level were evaluated using the DOT categories (Table I). Physical exertion job characteristics were semi-quantitatively classified as being not present, occasionally, frequently, or constantly present in the job (Table I).

TABLE I. Definitions of Physical Activity, Noise Intensity, and Job Characteristics

Exposure	Level	Definition, example in textile industry
Physical activity	Sedentary	Exerting up to 10 pounds of force occasionally, or a negligible amount frequently. Work involves sitting most of the time (e.g., receptionist)
	Light	Exerting up to 20 pounds of force occasionally, 10 pounds frequently, or a negligible amount constantly. Work involves walking or standing to a significant degree; or sitting most of the time while pushing or pulling arm or leg controls; or working at a production rate pace while constantly pushing or pulling materials (e.g., dyeing, filament cutting)
	Medium	Exerting 20–50 pounds of force occasionally, 10–25 pounds frequently, or up to 10 pounds constantly. Physical demand requirements are in excess of those for light work (e.g., carding, spinning)
	Heavy	Exerting 50–100 pounds of force occasionally, 25–50 pounds frequently, or 10–20 pounds constantly. Physical demand requirements are in excess of those for medium work (e.g., picking, foundry)
	Very heavy	Exerting >100 pounds of force occasionally, >50 pounds frequently, or >20 pounds constantly. Physical demand requirements are in excess of those for heavy work
Noise intensity level	Quiet	Library, hospital/medical clinic
	Moderate	Business office where typewriters are used, light traffic, textile finishing, manual screen printing, pattern layout
	Loud	Spinning, weaving, knitting
Job characteristics and physical demands[a]	Not present	Does not exist
	Occasional	Exists up to 1/3 of the time
	Frequently	Exists from 1/3 to 2/3 of the time
	Constantly	Exists 2/3 or more of the time

Examples from the Shanghai textile industry are given. Modified from US Department of Labor Dictionary of Occupational Titles [US Department of Labor, 1991].
[a]Includes stooping, crouching, reaching, handling, exposure to weather, extreme heat, extreme cold, atmospheric conditions, climbing, balancing, kneeling, crawling, wet/dry conditions.

Quantitative analyses examining the relations between miscarriage and exposures were conducted considering all pregnancies, and separately for first pregnancy. Analyses examining the outcome of all pregnancies were conducted using generalized estimating equations to control for within-women correlations between pregnancy outcomes [Diggle et al., 2002]. Secondary analyses limited to the outcome of the first pregnancy were conducted to eliminate within-woman correlation among multiple pregnancies and used logistic regression to estimate odds ratios (OR) and 95% confidence intervals (95% CI). For physical activity, all analyses were conducted using women in sedentary jobs as the reference group. For noise exposure, quiet jobs were the reference group as no women were employed in jobs with very quiet environments. Induced abortions and ectopic pregnancies were excluded. All analyses were adjusted for the woman's age at pregnancy (in 5-year age groups), woman's year of birth, highest level of education completed (never went to school, elementary school, high school, or college), the woman's smoking status during pregnancy (yes/no), the spouse's smoking status during pregnancy (yes/no), and the woman's alcohol use (never, ≤1/month, ≤1/week, >1/week). All analyses were conducted in STATA version 9.0 (Stata Corporation, College Station, TX).

RESULTS

The majority of women were first pregnant in their 20s, reported little alcohol consumption, and were nonsmokers. Body mass index (BMI) was low with 97% of women considered underweight or normal (Table II). These 1,427 women contributed a total of 4,237 pregnancies to the analysis. Of first pregnancies, 89.4% resulted in live birth, 5.8% in miscarriage, 3.3% in induced abortion, 0.9% in still birth, and 0.5% in ectopic pregnancy or other unspecified outcome. Out of all pregnancies in the women's reproductive history, 65.0% of all pregnancies resulted in a live born infant, 4.9% in miscarriage, 28.9% in induced abortion, and 0.6% still birth. Relative to women aged 20–24 at the time of the first pregnancy, an increased risk of miscarriage was found for women ages 15–19 years, although this elevation was not statistically significant. Elevated miscarriage risk (OR 8.4) was observed for women who smoked during pregnancy (Table II).

Relative to women in sedentary jobs, a reduced risk of miscarriage was found for women employed in jobs with light physical activity (OR 0.32, 95% CI: 0.17, 0.61, Table III) and medium physical activity (OR 0.43, 95% CI: 0.23, 0.80) over all pregnancy outcomes. Analyses restricted to first pregnancy outcome identified similar reductions with light or medium physical activity (Table III). Few women worked in jobs with heavy physical activity/strength, and no women were employed in jobs with very heavy physical activity/strength. Analyses adjusting for BMI yielded similar results (data not shown).

Elevated miscarriage risk with frequent occupational crouching was identified. Relative to women for whom crouching was not present, women employed in jobs requiring frequent crouching experienced 1.82 times the risk (Table III). Although few women were employed in jobs requiring constant crouching, an elevated risk was also observed (OR 3.23, 95% CI: 0.98, 10.70) when considering all pregnancies in the reproductive history.

TABLE II. Demographic and Pregnancy Characteristics of Women (n = 1,427) at the Time of the First Pregnancy

	n	%	OR[a]	95% CI[a]
Age at first pregnancy[b]				
15–19	45	3.2	2.61	0.89–7.70
20–24	316	22.1	1.00	Ref.
25–29	818	57.3	0.86	0.43–1.70
30–34	218	15.3	0.93	0.41–2.12
35+	30	2.1	1.60	0.42–6.04
Marital status at time of questionnaire[c]				
Married	1,304	91.4	1.00	Ref.
Widowed	96	6.7	0.74	0.25–2.20
Separated	5	0.4	∼	
Divorced	22	1.5	2.53	0.72–8.94
Alcohol consumption[c]				
Never	1,287	90.2	1.00	Ref.
≤1/month	42	2.9	0.77	0.18–3.28
≤1/week	36	2.5	0.40	0.05–3.01
>1/week	60	4.2	0.49	0.12–2.06
Smoking status during pregnancy[c]				
Did not smoke	1,421	99.6	1.00	Ref.
Smoked	6	0.4	8.44	1.45–49
Spouse's smoking status during pregnancy[c]				
Did not smoke	857	60.1	1.00	Ref.
Smoked	570	39.9	0.42	0.24–0.71
Body mass index (kg/m^2)[c]				
<19	570	39.9	1.28	0.81–2.00
19 < 25	818	57.3	1.00	Ref.
≥25	30	2.0	1.10	0.25–4.85
Highest level of education completed (years completed)[c]				
None (<5 years)	140	9.8	0.44	0.14–1.37
Elementary (5 years)	188	13.2	0.42	0.16–1.14
High school (8 years)	1,047	73.4	1.00	Ref.
College or over (≥11 years)	51	3.6	0.82	0.25–2.74

From these women, 4,237 pregnancies are contributed. Odds ratios (OR) and 95% confidence intervals (CI) for risk of miscarriage as the outcome of the first pregnancy associated with these demographic characteristics are presented.

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

[b]Logistic regression, adjusted for woman's year of birth.

[c]Logistic regression, adjusted for woman's year of birth and age at first pregnancy.

TABLE III. Physical Activity from Occupational Work and Risk of Miscarriage

	First pregnancy only						All pregnancies					
	Live or still birth (n = 1,288)		Miscarriage (n = 84)				Live or still birth (n = 2,811)		Miscarriage (n = 195)			
	n	%	n	%	OR[a]	95% CI[a]	n	%	n	%	OR[b]	95% CI[b]
Physical activity												
Sedentary	25	80.6	6	19.4	1.00	Ref.	63	84.0	12	16.0	1.00	Ref.
Light	732	94.9	39	5.1	0.18	0.07–0.50	1,508	94.4	89	5.6	0.32	0.17–0.61
Medium	495	93.2	36	6.8	0.24	0.08–0.66	1,176	93.0	89	7.0	0.43	0.23–0.80
Heavy	36	92.3	3	7.7	0.29	0.06–1.36	64	92.8	5	7.2	0.44	0.16–1.23
P-trend						0.95						0.70
Stooping												
Not present	556	94.2	34	5.8	1.00	Ref.	1,188	93.4	84	6.6	1.00	Ref.
Occasionally	446	94.1	28	5.9	1.03	0.61–1.75	975	94.8	54	5.2	0.84	0.58–1.22
Frequently	284	92.8	22	7.2	1.25	0.70–2.20	645	92.0	56	8.0	1.26	0.84–1.89
Constantly	2	100.0	0	0.0	—	—	3	75.0	1	25.0	3.23	0.98–10.70
P-trend						0.52						0.32
Crouching												
Not present	719	94.4	43	5.6	1.00	Ref.	1,551	93.8	103	6.2	1.00	Ref.
Occasionally	438	93.8	29	6.2	1.11	0.67–1.83	971	94.3	59	5.7	1.00	0.71–1.42
Frequently	131	91.6	12	8.4	1.54	0.77–3.08	289	89.8	33	10.2	1.82	1.14–2.93
P-trend						0.26						0.06

[a]OR, odds ratio; CI, confidence interval. Logistic regression analyses adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth.
[b]Generalized estimating equations, analyses adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth.

Relative to women employed in quiet jobs, no elevations in miscarriage risk were identified for women holding jobs considered to have moderate or loud noise levels (Table IV). Frequent or constant occupational exposure to extreme weather was associated with a 2.70-fold increase in risk.

DISCUSSION

The main findings from this study were reduced miscarriage risks associated with light to moderate occupational physical activity, and an elevated risk for women working in jobs that required crouching. No associations were observed for noise exposure. This present study used a combination of weight lifted, frequency of lifting, and physical requirements of the job to determine overall physical activity level, and identified a reduction in risk of miscarriage for women working in positions with moderate to light physical activity compared with women in sedentary jobs. Self-reported high physical strain (frequent lifting of heavy loads) has been associated with losses around the time of implantation, with the highest risks observed after 5 weeks (hazard ratio 4.8, 95% CI: 2.0, 11.4) [Hjollund et al., 2000]. However, with a self-reported scale of physical strain (no, light, moderate, very high), women with identical activities may report different physical strain levels. In our cohort, physical activity tended to be mild or moderate, with few women working in jobs involving heavy or very heavy occupational physical activity. Although heavy or strenuous recreational and occupational physical activity during pregnancy has been of concern due to the potential for reduced fetal oxygen exchange, decreased uterine blood flow, increased fetal and maternal pH, and hypoxia [Mittelmark et al., 1991], moderate physical activity has shown no overall adverse effect on oxygen transfer to the fetus. Moderate recreational physical activity has also been associated with beneficial outcomes later in pregnancy [Dempsey et al., 2005], with no consistent adverse effects on birth weight or preterm delivery. Alternatively, the risk reductions identified with light or medium physical activity may reflect a preferential shift of less healthy women to sedentary jobs. Although detailed health status information during pregnancy was unavailable, complete career work history data were available. Women holding sedentary jobs at the time of pregnancy held the same median number of jobs as their counterparts employed in light, medium, or heavy physical activity jobs, suggesting that less healthy women were not more likely to be moved into sedentary positions. Governmental universal employment policy also ensured that all pregnant women worked until shortly before the due date, and returned to the same job position after maternity

TABLE IV. Noise and Physical Characteristics of a Woman's Occupation and Risk of Miscarriage

	First pregnancy only						All pregnancies					
	Live or still birth (n = 1,288)		Miscarriage (n = 84)				Live or still birth (n = 2,811)		Miscarriage (n = 195)			
	n	%	n	%	OR[a]	95% CI[a]	n	%	n	%	OR[a]	95% CI[a]
Noise												
Quiet	31	91.2	3	8.8	1.00	Ref.	58	92.1	5	7.9	1.00	Ref.
Moderate	164	95.3	8	4.7	0.55	0.13–2.25	307	93.3	22	6.7	0.87	0.29–2.62
Loud	1,093	93.7	73	6.3	0.77	0.22–2.72	2,446	93.6	168	6.4	0.97	0.35–2.66
P-trend						0.77						0.80
Exposure to weather												
Not present/occasional	1,279	94.0	82	6.0	1.00	Ref.	2,792	93.6	191	6.4	1.00	Ref.
Frequently/constantly	9	81.8	2	18.2	3.25	0.66–15.94	19	82.6	4	17.4	2.70	1.02–7.17
Extreme heat												
Not present/occasional	1,212	93.7	81	6.3	1.00	Ref.	2,645	93.4	187	6.6	1.00	Ref.
Frequently/constantly	76	96.2	3	3.8	0.52	0.16–1.72	166	95.4	8	4.6	0.65	0.32–1.30

[a]OR, odds ratio; CI, confidence interval. Logistic regression analyses adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth.
Generalized estimating equations, analyses adjusted for age, education, smoking, alcohol, spousal smoking, woman's year of birth.

leave. Most women in this industry worked in one or two jobs over their entire working career and job movement tended to be within the same industry [Camp et al., 2003]. Thus preferential movement of women with early pregnancy and health concerns into sedentary occupations is not a likely explanation for the results.

Occupational heavy lifting has been previously associated with both risk reductions and elevations [McDonald et al., 1986, 1988; Taskinen et al., 1990]. Lifting more than 10 kg (22 pounds) more than 50 times per week was associated with more than a 3-fold elevation in risk of miscarriage compared with women not employed during pregnancy [Taskinen et al., 1990] and lifting of ''heavy'' weights more than 15 times per day was associated with a 50% increase in risk for women working in the manufacturing sector [McDonald et al., 1988]. Similar to the current study, all of these studies evaluated both a weight and the frequency with which the weight was lifted. However, it is difficult to reconcile these various weights and frequencies. Prior studies also relied on women to self-report the physical aspects of the occupation thus misclassification of exposure is of concern, whereas the current study used an independent external occupational framework to classify exposures.

Standing and bending have additionally been observed to be associated with elevations in risk [Florack et al., 1993; Eskenazi et al., 1994; El-Metwalli et al., 2001], although results have been mixed [McDonald et al., 1988; Swan et al., 1995; Fenster et al., 1997; Hjollund et al., 2000]. Compared to women standing for less than 3 hr per day, women that stood for at least 8 hr per day had a 60% higher risk of miscarriage (95% CI: 1.1, 2.3), with an even stronger association with second trimester loss [Eskenazi et al., 1994]. Women working in occupations involving at least 1 hr of bending daily had a 3.2-fold (95% CI: 1.27, 9.78) increase in risk [Florack et al., 1993]. We observed a significant effect of crouching, which involves postural changes such as bending, but not with stooping in the job.

Elevations in miscarriage risk associated with postural effects may be due to increases in intra-abdominal pressure, leading to decreased blood flow to the fetus [Lindbohm and Taskinen, 2000]. Bending and lifting postures may increase intra-abdominal pressure approximately 8 times the pressure seen in an upright walking posture [Florack et al., 1993]. Alternatively, fetal growth may be affected due to reduced maternal venous blood return while upright or standing due to increased blood volume but unchanged blood pressure during pregnancy [Mittelmark et al., 1991]. Physiological changes during pregnancy increase lower back stress and change the center of gravity, increasing forces on leg joints and muscles compared to nonpregnancy [Mittelmark et al., 1991]. Weight-bearing exercises are also performed less efficiently and require more energy because they include a component of body weight.

Conflicting results in the literature may be due to differences in data collection and differences in definitions of physical activity and physical exertion. Self-reported exposure information and various definitions have been proposed. Prior studies have typically relied upon self-

reported job characteristic information similar to the classifications in the current study (e.g., crouching or stooping) and/or created study-specific scales of physical activity which are of limited generalizability. The current study used occupational physical activity and physical exertion information which are readily applicable to other occupational settings. Our measure of physical activity is a general multicomponent index combining many characteristics of each woman's job.

This study's semi-quantitative JEM used information from the US DOT to assign physical activity exposures. Although the DOT was developed for US jobs using assessments conducted during 1930–1980s, textile industry production processes during this time period were likely similar between countries. Use of DOT data from US textile processes with potentially higher mechanization levels would not be expected to change physical demands on textile workers, merely the number of women working in the textile process. DOT job titles and our textile industry-specific classification of job titles were not always a perfect match, with more detailed job titles in the DOT at some times and more detailed job titles in our textile industry-specific classification scheme at other times. When level of detail regarding a job differed between classification schemes, the most likely match was selected, potentially leading to exposure misclassification. The DOT also does not assign absolute amounts of time spent performing a job characteristic, such as crouching, and some exposure misclassification may have occurred. However, the DOT was sufficient to allow us to classify and rank jobs and to distinguish between jobs with no, little, moderate, or high amounts of physical activity or physical exertion. Although some exposure misclassification for any one job might have occurred, across categories of intensity the potential effects of exposure misclassification are likely minimized. It is also likely that exposure is under-estimated, with only those women having the highest levels of exposure classified as exposed, and women with infrequent exposures classified as unexposed. However, physical activity was independently assigned without knowledge of the outcome, so misclassification would be expected to be nondifferential and lead toward the null result. Only occupational physical activity was examined using the JEM, and the role of any recreational physical activity was not considered with our JEM-based exposure assessment. Self-reported combined occupational and recreational physical activity was recorded for these women and was similarly distributed when compared with the occupational physical activity exposure distribution, with only 1.5% of women reporting ''heavy manual work or lifestyle'' versus 2.8% of women assigned heavy physical activity with the DOT. Thus, the role of recreational physical activity is not expected to unduly influence these associations with occupational physical activity.

Results surrounding spousal (male) smoking are unexpected. Spousal smoking was determined retrospectively through the woman's report, so may be under-reported. Few women (0.4%) reported smoking during pregnancy.

Miscarriage information in this study relied upon self-reported reproductive history. It is possible that miscarriage rates were under-reported. Self-reported miscarriages have been shown to have imperfect recall [Wilcox and Horney, 1984]. Approximately 6% of first pregnancies among young healthy women resulted in miscarriage, slightly lower than that seen in a similar study of textile workers which relied upon biomarker identification of pregnancies and miscarriage prospectively [Venners et al., 2005] and can provide an upper bound on rates. Validation of reproductive history was not possible due to the retrospective nature of the current study. Sociocultural factors in this population and time period supporting accurate recall of reproductive history included governmental family planning policies and universal health care access through factory-based clinics. Under the governmental family planning policies, pregnancy occurrence was closely monitored and therefore care-seeking patterns or inadequate access to care did not play a role in the identification of pregnancies or pregnancy loss. Universal health access also reduces the possibility for under-ascertainment of early fetal losses to impact reporting.

It is important to note that this study is virtually free of potential bias due to more fertile workers preferentially leaving the workplace (infertile worker bias). Due to the governmental universal employment policies in place for this cohort of women, pregnant women worked until just before the due date of the child, then returned to the same job position after maternity leave was concluded. These policies therefore allowed this study of workplace exposures and reproductive risks to be free of potential biases found in most other occupational settings.

Additional strengths of the current study include availability of detailed reproductive history data for each woman and complete work history data in the textile industry, and data on potential confounders. Occupational exposures were assigned using written industry personnel records for each woman, and very little misclassification is expected to have occurred because work history was found in textile industry factories for 99% of women. There also tended to be very little job movement over the women's working careers [Camp et al., 2003].

This study identified sedentary work and crouching as risk factors for miscarriage risk with protective light and moderate physical activity in this cohort of Shanghai textile workers. These findings are generally consistent with previous literature on occupational and recreational physical activity. Similar findings in other occupational cohorts of women will be needed to strengthen causal inferences.

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