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ORIGINAL ARTICLE

Occupational injury risk by sex in a manufacturing cohort

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Received 6 January 2014
Revised 25 April 2014
Accepted 25 May 2014
Published Online First 12 June 2014

ABSTRACT

Objectives This study expands previous research comparing injury risk for women and men in a cohort of 24 000 US aluminium manufacturing workers in 15 facilities from 2001 to 2010.

Methods We compared injury rates (all injury, first aid, medical treatment, restricted work and lost work time) by sex and by job and sex. Using a mixed effect modelling approach, we calculated ORs and 95% CIs adjusting for age, job tenure, ethnicity and year as fixed effects and person, job and plant as random effects. Additionally, we modelled the data stratified by plant type to examine potential differences in injury risk between smelter (generally recognised as more hazardous) and fabrication production environments.

Results Risk of injury was higher for women in four out of the five injury outcomes: all injuries combined (OR: 1.58, CI 1.48 to 1.67), injuries requiring first aid (OR: 1.61, CI 1.54 to 1.70), injuries requiring medical treatment (OR: 1.18, CI 1.03 to 1.36) and injuries requiring restricted work (OR: 1.65, CI 1.46 to 1.87). No difference in the risk of lost time injury by sex was found in this cohort. Analyses stratified by plant type showed similarly elevated injury risk for women, although the risk estimates were higher in smelters than fabrication plants.

Conclusions To our knowledge, this is the largest single-firm study examining injury risk by sex with sufficient data to appropriately adjust for job. We show a consistently higher injury risk for women compared with men in the smelting and fabrication environments.

What this paper adds

- Much occupational research examining injury risk by sex is confounded by an inability to control for job, a critical determinant in injury risk.
- Because men often work in more dangerous jobs than women and thus have higher overall injury rates, the injury risk for women working in traditionally male jobs is underestimated.
- Adjusting for job, plant type and tenure in a large cohort of medium and heavy manufacturing workers, this study shows women are at higher risk for injuries requiring first aid, medical treatment and work restriction. We did not find a statistically significant difference in injuries requiring lost time between men and women.

INTRODUCTION

Globally, women's participation rate in the workforce has been steady at just over 50% for the past 25 years.[1] In the USA, women comprise 27% of the manufacturing workforce[2] and almost half (47%) of the labour force with the annual growth of women in the labour force projected at approximately 0.7% during the next decade.[3 4] With 4 in 10 US households with children now having the mother as the primary source of income and women predicted to continue to increase in number in the global labour force, understanding the physical and psychosocial impact of work on women is crucial.[5 6]

Women have been participating in traditionally male dominated workplaces for years; however, our understanding of how workplace risks affect men and women differently has been woefully lacking.[7 8] Incidence rates reported by the Bureau of Labor Statistics consistently show lower injury risk for women compared with men in the manufacturing of durable goods industry.[9] Even as researchers examined individual occupations within industrial classification, the statistics continued to show higher occupational injury and fatality rates for men, suggesting that women were naturally safer workers.[10–13] Researchers then began to question whether the increased risk of injury for men was actually a reflection of the different jobs men and women performed within occupational and industry groups rather than of an inherent occupational risk.[12–15] Smith *et al* found that classifying occupational codes into physical demand rankings showed that women in manual jobs had a higher risk for chronic musculoskeletal injuries compared with men, but not for acute traumatic or strains and sprain injuries.[16] More recently, researchers have begun to acknowledge a significant gap in injury epidemiology whereby injury risk is assessed not only at the industry and occupation levels, but also at the job and job task levels.[8 17–20] Differential distribution among jobs by men and women in the same occupation is likely the reason so much research to date has suggested an ambiguous or even protective effect of being female in the workplace on injury risk.

In addition to data limitations regarding job and differential job task assignment, research has been further stymied by inadequate understanding of how work affects men and women differently, both

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To cite: Tessier-Sherman B, Cantley LF, Galusha D, *et al*. *Occup Environ Med* 2014;**71**:605–610.

physically and psychologically.[8] Individual-level factors previously associated with injury risk in occupational cohorts include an elevated body mass index and smoking.[21–24] Unknown to date, however, is whether either of these factors contributes differentially to injury risk for male and female workers. Previous evidence also suggests an association between having small children at home and increased risk of occupational injury among female aerospace workers, though this association has not been studied among male workers.[25]

In 2009, the investigators found female aluminium smelter workers at substantially greater risk for all forms of occupational injury compared with male workers after accounting for job.[17] Aluminium smelter facilities, which include large-scale potrooms, molten metal tapping and transport, and anode baking furnaces, are recognised as physically demanding, heavy manufacturing environments with many inherent hazards, including intense heat exposure. In comparison, aluminium fabrication facilities, where aluminium ingots are heated and rolled into sheets or otherwise moulded, vary in the size of parts fabricated and are typically less physically demanding environments. Consequently, fabrication facilities generally employ more female workers compared with smelters. Recognising both the unique nature of aluminium smelting work and the small proportion of female smelter workers, this study seeks to build on our previous work by expanding the study population to include both aluminium smelter and production workers, thus using a larger and more representative manufacturing population with which to study sex differences in occupational injuries.

With an important gap to fill in understanding the causes of occupational injury, this study's primary objective is to assess the injury risk among women compared with men in a cohort of medium and heavy manufacturing workers in the aluminium industry. We will pay particular attention to the specific job categories, plant type and work experience of employees as being essential determinants of risk.

METHODS

Study cohort and data

This study employed data from a longstanding academic–corporate partnership between the investigators and a multinational aluminium manufacturing company, the purpose of which is to improve health and safety outcomes of employees. Data from six smelting plants and nine fabricating plants in the USA, representing geographically diverse regions of the country, were used to create a cohort for the study period 1 January 2001 through 31 December 2010.

Employee demographics were available through the company human resource database that includes employee sex, date of birth, plant location, job title, job category (hourly or salary), hire date, and dates of job change, transfer, leave of absence and termination, where applicable. Injury events were available through the company incident surveillance system that requires all plant locations to track not only Occupational Safety and Health Administration (OSHA) recordable events (medical treatment, restricted work and lost work time) but also first aid events. Data fields include the employee injured, date of injury, plant location, body part injured, nature of injury and injury severity. For the purpose of this analysis, injuries were stratified into either acute or musculoskeletal disorder (MSD) injuries using the nature of injury field. Acute events included abrasions, burns, contusions, fractures, bites and stings, lacerations, punctures, amputations, blisters, dislocations, foreign bodies and eye injuries. MSD injuries included instantaneous and non-instantaneous strains and sprains, pain in joint, non-specific musculoskeletal pain and hernias. Injury severity classifies each event into one of four categories: injuries requiring only first aid, injuries requiring medical treatment beyond first aid by a healthcare professional, injuries requiring work restrictions and injures requiring lost work time.

In order to meaningfully assess the impact of job on injury risk, each job title from the human resources database was assigned to a standardised job category. This process, previously described,[26] allowed the investigators to collapse similar job titles across plants into standardised categories so that jobs with comparable demands could be compared. This process created 51 standardised job categories for use in this analysis. Linkage between company datasets was achieved through the development of an encrypted unique identifier for each employee to ensure human subject privacy.

Additional data used include the medical claims database and occupational health datasets. The claims database is received annually from a central data processing company for all employees and their dependents participating in the company's preferred provider organisation. Using these data we compiled a list of employees and the number and age of child dependents. Occupational health data were provided to the investigators in one of two ways: some plants maintain an electronic database, to which the investigators have access, of data gathered from mandatory health screenings, while other plants merely record such data in the employees' paper charts. The investigators have abstracted data from employee medical records at certain plants not using the electronic database. Data collected include smoking history and body mass index. Detailed descriptions of these datasets and the linkage system have been previously published.[26–28]

All hourly male and female employees working in the 15 locations were included in the analysis. In order to avoid biased estimates due to small numbers of males or females in a particular job category, we limited our study sample to those jobs with a minimum of 10 male and 10 female employees contributing at least 50 person-years each for the 10 years studied. These criteria retained 93% of the hourly workforce.

Statistical analysis

Descriptive statistics were calculated for the whole cohort and by sex. Bivariate injury rates per 100 person-years were calculated by dividing the number of sex-specific injury events by the summed number of sex-specific person years, multiplied by 100. Injury rates by job category, acute versus MSD injury, body part and injury severity were also calculated. In the multivariate analysis, a random intercept model was chosen to accommodate the repeated measures by person-job and associated correlation. A binomial distribution was chosen with a logit link and summed person months for each person-year-job as the injury rate denominator. Fixed effects included sex, age, ethnicity, job tenure (<1 year vs ≥ 1 year) and year to account for the potential temporal trend in injury rate. The intercepts for each person clustered within job and job clustered within plant were modelled as random effects to allow for between-person and between-job variation, and an unstructured covariance structure was chosen. Because of the nonlinear effect of year, year was included as a categorical variable. Separate analyses were run for all injury outcomes of interest, including all injuries, OSHA recordable injuries (medical treatment, restricted work and lost time), acute injury versus MSD, as well as the prevalent body parts injured (hand and finger, shoulder and arm, wrist and elbow, and lower back). In order to examine the influence of

Table 1 Demographics of a US aluminium manufacturing workers cohort, by sex, 2001–2010

	Male		Female		All		
	N	%	N	%	N	%	p Value
Employees	18 893	78.87	5063	21.13	23 956	100.00	–
Person-years	85 102	79.68	21 697	20.32	106 799	100.00	–
Age, mean (SD)	44.18 (12.71)		44.39 (11.87)		44.22 (12.53)		0.30
No. of jobs held, mean (SD)	1.55 (0.94)		1.53 (0.89)		1.55 (0.93)		0.20
Ethnicity							<0.001
Black	2298	12.16	984	19.44	3282	13.70	–
Hispanic/Latino	1146	6.07	445	8.79	1591	6.64	–
White	15 138	80.12	3525	69.62	18 663	77.91	–
Other	311	1.65	109	2.15	420	1.75	
Plant type	–	–	–	–	–	–	<0.0001
Smelter	8665	45.86	678	13.39	9343	39.00	–
Fabrication	10 228	54.14	4385	86.61	14 613	61.00	–

manufacturing process on injury risk, we conducted separate analyses stratified by plant type.

To investigate whether previously reported individual-level factors could have a confounding effect on the relationship between sex and injury, we conducted two sensitivity analyses that incorporate (1) having small children at home and (2) two cardiovascular risk factors—body mass index and smoking history—into our statistical models.

All statistical analyses were performed with SAS V.9.2 (SAS Institute Inc., Cary, North Carolina, USA). All p values were two-sided, and a value of less than $\alpha=0.05$ was considered statistically significant. Ethical approval for this study was granted by the Yale University School of Medicine Human Investigations Committee.

RESULTS

The study cohort comprised 23 956 hourly employees at 15 manufacturing locations, with a total of 106 799 person-years (table 1). Female employees made up 21% of the workforce with a mean age of 44 years of age and 1.53 standard jobs worked during the 10-year study period. In total, 70% of the female workforce was white and 87% worked in the fabricating plants. There was no significant difference between the age or number of jobs held between men and women; however, there were significant differences between ethnicity and plant type by sex.

Table 2 Injury rates of US aluminium manufacturing workers, by sex, per 100 person-years

	Male	Female	All
	n (rate)	n (rate)	n (rate)
All injuries	13 377 (15.72)	4069 (18.75)	17 446 (16.33)
By severity			
First aid	9920 (11.66)	3353 (15.45)	13 273 (12.43)
Medical treatment	1519 (1.80)	308 (1.42)	1837 (1.72)
Restricted work	1747 (2.05)	376 (1.73)	2123 (1.99)
Lost work time	181 (0.21)	32 (0.15)	213 (0.20)
By injury type			
MSD	4727 (5.55)	1159 (5.34)	5886 (5.51)
Acute injury	8650 (10.16)	2910 (13.41)	11 560 (10.82)
By body part			
Hand/finger	3709 (4.36)	1479 (6.82)	5188 (4.86)
Shoulder/arm	1503 (1.77)	496 (2.29)	1999 (1.87)
Wrist/elbow	1252 (1.47)	454 (2.09)	1706 (1.60)
Lower back	1255 (1.47)	250 (1.15)	1505 (1.41)

MSD, musculoskeletal disorder.

Table 2 shows the injury rates per 100 person-years by sex. Female employees had an all injury rate of 18.75 compared with men at 15.72. First aid events represented 76% of all injuries and women had a higher first aid rate at 15.45 compared with men at 11.66. OSHA recordable injuries, composed of medical treatment, restricted work and lost time injuries, showed slightly elevated injury rates for men compared with women, as did all MSD injuries. Women had higher acute injury rates as they also did for hand/finger, shoulder/arm and wrist/elbow injuries. Men had slightly higher injury rates for those injuries affecting the lower back.

The distributions of male and female employees by standardised job category are listed in table 3. Those jobs with the largest percentage of female employees include wax cell operator, inspection operator, pack/ship operator, metal cell operator and administration, while those with the smallest percentage include mechanical maintenance, anode changer, electrical maintenance and crane operator. The all injury rates per 100 person-years were substantially higher for women in all job categories. There was a much larger disparity in OSHA recordable injury rates between men and women for smelter jobs than jobs only in fabrication plants or those in both smelter and fabrication plants. Although closer to male injury rates, those for females in fabrication jobs were consistently higher except for crane operators and administrative jobs.

After adjusting for job category, plant, age, tenure in job, ethnicity and year, the results of the multivariate analyses show an increased risk of injury for female employees in four of the five injury outcomes (all injuries combined, first aid, medical treatment, restricted work), both acute and MSD injury types, and the four body part outcomes (table 4). Stratified analyses by plant type, smelter versus fabrication, also showed consistently higher injury risk for females, although the risk estimates were higher for women in the smelters. There was not a statistically significant difference in the risk of lost time injury by sex in this cohort.

In the subset of employees for which we had data on the number of children under the age of six (86% of the full

Table 3 Sex distribution and injury rates for the most common aluminium manufacturing jobs

Standardised job category	n (% female)	All injury rate/100 PY		TR rate/100 PY	
		Male	Female	Male	Female
Mechanical maintenance, S/F	3258 (3.90)	17.32	20.43	4.97	5.52
Mobile equipment operator, S/F	2572 (12.91)	10.39	20.99	2.53	4.14
Wax cell operator, F	2273 (76.33)	11.01	16.33	1.50	1.76
Inspection operator, S/F	2209 (42.46)	12.29	17.21	2.63	2.83
Potroom operator, S	2188 (7.04)	24.45	55.75	6.12	12.72
Anode changer, S	1927 (3.84)	50.30	89.60	14.99	44.80
Caster operator, S	1689 (6.87)	16.24	36.30	4.15	10.16
Pack/ship operator, S/F	1596 (29.82)	12.33	16.09	2.73	4.06
Electrical maintenance, S/F	1401 (4.21)	10.23	15.30	2.77	3.56
Caster furnace operator, S	1382 (7.89)	16.53	43.85	4.29	12.60
Metal cell operator, F	1366 (41.95)	14.22	21.15	1.42	1.58
Sheet/plate mill operator, F	1097 (20.15)	10.87	22.99	3.56	5.93
Crane operator, S/F	955 (4.50)	20.09	26.20	6.02	3.93
Facilities and grounds operator, S/F	819 (17.95)	13.29	12.98	3.41	4.33
Administration, S/F	779 (47.24)	3.21	2.63	1.13	0.61

F, fabrication; S, smelter, S/F, both smelter and fabrication; TR, OSHA recordable.

cohort), 12% of male employees and 6% of female employees had at least one child under the age of six. There was no statistically significant association between having young children on all injury or OSHA recordable injury risk on all employees or when looking only at female employees. In the subset of employees for which we had known cardiovascular risk factors (48% of the full cohort), inclusion of smoking status (ever/never) and body mass index category (normal, overweight, obese) resulted in an unchanged risk of all injury for women (OR: 1.59, 95% CI 1.50 to 1.69) and total recordable injury (OR: 1.46, 95% CI 1.30 to 1.64).

DISCUSSION

Our study builds upon previous work focusing solely on jobs in the aluminium smelting industry that found an increased risk of all injury outcomes for female smelter workers.[17] By examining workers in aluminium smelting and fabricating plants, our aim was to discern whether the elevated risk of injury for female workers extended beyond the most physically demanding smelter jobs to more common production jobs. The analyses show a consistent association between female sex and injury outcomes in our cohort throughout the 10-year study period. Separate analyses by injury severity and injury type indicate a sustained increased risk of injury for female employees. Results for acute, traumatic injuries demonstrate an increased risk that extends beyond the more traditionally accepted susceptibility of females to MSDs.

There are several potential explanations for the injury disparity in female employees shown here. Qualitative research examining injury risk among female construction workers suggests that a variety of psychosocial factors, including skill underutilisation, gender discrimination and overperformance, were associated with adverse psychological and physical outcomes.[29 30] Likewise, the investigators found that female construction workers' greatest concerns regarding workplace health and safety included the lack of personal protective clothing and tools designed for women, adequate job training and appropriate restroom facilities.[31] Similar research has found that men often have more job control in traditionally male- and female-dominated jobs and that men typically receive more on the job safety training than women.[32–34] These findings suggest that the psychosocial aspects of women working in traditionally male occupations as well as the lack of adequate safety training may well be causal factors in the increased injury risk for female employees.

Another potential explanation for our results found in the literature is that women may report injuries more than men. Zwerling *et al* introduce this possibility as a correlate to women seeking medical care more often than men.[20] However, similar to a study of electric utility workers, our study found that women were at higher risk for more serious injuries, including those requiring medical treatment, and restricted work.[32] If over-reporting were indeed a contributing factor in the increased risk of injury, one would expect that risk to disappear when looking only at severe injuries, and this was not the case. The majority of injuries (76%) sustained by our cohort during

Table 4 Risk of injury by plant type: multivariate mixed effects model results, female versus male

	Smelter		Fabrication		All plants	
	OR	95% CI	OR	95% CI	OR	95% CI
All injuries	1.52	1.40 to 1.64	1.59	1.50 to 1.68	1.58	1.48 to 1.67
By severity						
First aid	1.48	1.36 to 1.62	1.67	1.57 to 1.78	1.61	1.54 to 1.70
Medical treatment	1.30	1.01 to 1.68	1.14	0.97 to 1.34	1.18	1.03 to 1.36
Restricted work	1.94	1.61 to 2.33	1.47	1.25 to 1.73	1.65	1.46 to 1.87
Lost work time	1.85	0.87 to 3.95	0.91	0.58 to 1.42	1.01	0.68 to 1.50
By injury type						
MSD	1.53	1.36 to 1.73	1.65	1.50 to 1.82	1.61	1.49 to 1.73
Acute	1.52	1.38 to 1.68	1.57	1.47 to 1.67	1.56	1.48 to 1.65
By body part						
Hand/finger	1.46	1.26 to 1.69	1.51	1.38 to 1.65	1.50	1.39 to 1.62
Shoulder/arm	1.52	1.22 to 1.89	1.56	1.35 to 1.81	1.56	1.38 to 1.76
Wrist/elbow	1.57	1.25 to 1.97	2.02	1.74 to 2.35	1.85	1.63 to 2.09
Lower back	1.26	0.98 to 1.61	1.23	1.02 to 1.49	1.24	1.07 to 1.44

Adjusted for job category, plant, age, tenure in job, ethnicity and year as fixed effects; person within job and job within plant as random effects.
MSD, musculoskeletal disorder.

the study period were events requiring first aid treatment only. Similar proportions of minor versus more serious injuries have been consistently observed among cohorts from the study company.[26 35] Because we found elevated injury risk for female workers for injury events requiring first aid only as well as those requiring medical treatment or work restrictions, we do not believe the proportion of minor versus more severe injuries is meaningful to the associations we report here.

Research examining the physiological differences between males and females performing repetitive tasks has shown that despite doing identical tasks females exhibited higher muscular activity as a percentage of their maximum voluntary effort and a higher rate of MSDs of the neck and upper extremities.[36] Although many biological characteristics and social roles for men and women overlap, certain manufacturing jobs and tasks were likely designed to fit traditionally male traits and roles and therefore may require proportionally greater demand for female workers.[8]

Potentially contributing lifestyle factors that were not included in our main analyses but have been shown previously to have an impact on injury risk include body mass index, smoking history and having children under 6 years of age.[21 22 25] Because these data were only available for subsets of our cohort, we conducted two sensitivity analyses. We found no association between having children under the age of six in our sensitivity analysis on injury risk; however, this is likely the result of very few women with small children working in this industry. While body mass index and past or present smoking history were both positively associated with risk of injury, neither variable had a differential impact on women, and our point estimates remained the same as in our primary analysis.

Additional factors for which were unable to adjust include shift patterns, both consecutive and cumulative, the use of external medical providers to address an occupational injury and taking personal time to recover from an unreported injury.[27 37] Manufacturing companies often need to ramp up production depending on business needs, and this may in turn increase the risk of injury. Likewise, seeking care outside of the workplace or simply taking time off to address an injury could mask injury incidence in this cohort. However, we have no reason to suspect that such occurrences vary by sex for this cohort and would therefore have a confounding effect on our findings. Future study examining shift patterns on injury risk by sex is warranted.

There are some limitations to this report that merit discussion. First, although we adjusted for job category in our multivariate analyses, data limitations prohibited any analysis at the job task level. While we have no evidence suggesting that male and female workers in the same job category perform different job tasks, specific job tasks may pose substantially higher risk for women. For example, job tasks requiring high levels of force generation by upper body muscle groups, such as manually replacing spent carbon anodes or changing out machine dies, would place greater physical demand on the average female worker compared with the average male worker. Second, we were unable to adjust for actual hours worked, which could confound our results if women work substantially more hours than men performing comparable jobs. Although previous work has shown an association between working extended hours and injury risk,[2 7] no differential sex effect was reported. In a sample of this cohort for which we have the total number of annual hours worked, we found that female workers on average work 200 fewer hours a year and 150 fewer overtime hours a year compared with their male counterparts, suggesting that our results may, if anything, underestimate the higher injury risk for women. Third, Kubo *et al* reported increased injury risk for employees with chronic health conditions, including heart disease, respiratory illnesses and depression.[35–38] Although a specific pathway responsible for this increased risk was not tested, Kubo hypothesises fatigue due to either the illness, comorbidities or treatment may be responsible. Despite these limitations, there is no evidence that these factors would affect men and women differently.

Finally, although this study focuses on injury risk in the aluminium industry, many of the jobs included herein are common in many manufacturing environments. These include mobile equipment operators, electrical and mechanical maintenance, crane operators and machine operators. Therefore, future research should not only address other industries but also explore psychosocial demands of work that may differentially impact men and women's risk of injury. As the rate of women in the workplace continues to rise and the global manufacturing economy rebounds, employers and unions should dedicate resources to better understanding and mitigating the differential risk of injury for women as a function of job design, job training and improved safety cultures. Managing these aspects of the work environment for all workers, irrespective of sex, may benefit employers and workers alike.

Contributors BT-S, LFC and OAT conceived of and developed the study design. BT-S and DG compiled the data for analysis; BT-S and LFC conducted the data analysis and literature review and drafted the initial manuscript. MDS, MRC, BT-S, LFC, OAT and DG participated in data interpretation. All authors participated in reviewing, critically revising and finalising the manuscript.

Funding This research was funded by grants from the National Institute on Aging (Disease, Disability and Death in an Aging Workforce, NIH/NIA, 1 R01 AG026291-06) and a contract with Alcoa, Inc.

Competing interests All authors receive a portion of their compensation at Yale and Stanford through a unique academic–corporate relationship, the purpose of which is to develop workplace safety and occupational health policies. Funding agencies had no direct influence on the design or analysis of this manuscript.

Ethics approval Yale University School of Medicine Human Investigation Committee (IRB).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement As an alternative to providing a de-identified dataset to the public domain, we allow access for the purpose of reanalyses or appropriate 'follow-on' analyses by any qualified investigator willing to sign a contractual covenant with the host institution limiting use of data to a specific agreed upon purpose and observing the same restrictions as are limited in our contract with Alcoa, such as a 60-day manuscript review for compliance purposes.

REFERENCES

1 United Nations Department of Economic and Social Affairs. *The World's Women 2010: Trends and Statistics*. https://unstats.un.org/unsd/demographic/products/Worldswomen/WW_full%20report_color.pdf (accessed 4 Apr 2014).
2 National Women's Law Center. *Still No Recovery for Women in the Manufacturing Sector: Manufacturing Employment Trends for Women and Men, 2008–2013*. http://www.nwlc.org/sites/default/files/pdfs/manufacturing_employment_trends_2008-2013_fs.pdf (accessed 31 Aug 2013)
3 United States Department of Labor Bureau of Labor Statistics Women in the Labor Force: A Databook, December 2011. http://www.bls.gov/cps/wlf-databook-2011.pdf (accessed 27 Jul 2013).
4 Toossi M. Labor force projections to 2020: a more slowly growing workforce. *Mon Labor Rev* 2012;135:43–64.
5 Wang W, Parker K, Taylor P. *Breadwinner Moms*. Pew Research, Social & Demographic Trends. http://www.pewsocialtrends.org/2013/05/29/breadwinner-moms/ (accessed 5 Sep 2013).
6 United States Department of Labor, Bureau of Labor Statistics. *Projections Overview: Occupational Outlook Handbook*. http://www.bls.gov/ooh/About/Projections-Overview.htm (accessed 5 Sept 2013).

7 Chen G-X, Hendricks KJ. Nonfatal occupational injuries among African American women by industrial group. *J Safety Res* 2001;32:75–84.
8 Messing K, Punnett L, Bond M, *et al*. Be the fairest of them all: challenges and recommendations for the treatment of gender in occupational health research. *Am J Ind Med* 2003;43:618–29.
9 United States Department of Labor, Bureau of Labor Statistics. *Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work, 2011*. http://www.bls.gov/news.release/pdf/osh2.pdf (accessed 27 Jul 2013).
10 Lin Y-H, Chen C-Y, Luo J-L. Gender and age distribution of occupational fatalities in Taiwan. *Accid Anal Prev* 2008;40:1604–10.
11 Lin Y-H, Chen C-Y, Luo J-L. Statistical analysis of occupational fatalities in construction workers. *J Occup Saf Health* 2011;19:75–84.
12 Hoskins AB. Occupational injuries, illnesses, and fatalities among women. *Mon Labor Rev* 2005;128:31–7.
13 Root N, Daley JR. Are women safer workers? A new look at the data. *Mon Labor Rev* 1980;103:3–10.
14 Toscano GA, Windau JA, Knestaut A. Work injuries and illnesses occurring to women. In: *Compensation and Working Conditions*. U.S. Bureau of Labor Statistics, 1998:16–23. http://www.bls.gov/opub/cwc/archive/summer1998art3.pdf (accessed 27 Jul 2013).
15 Blue CL. Women in nontraditional jobs: is there a risk for musculoskeletal injury? *AAOHN J* 1993;41:235–40.
16 Smith PM, Mustard CA. Examining the associations between physical work demands and work injury rates between men and women in Ontario, 1990–2000. *Occup Environ Med* 2004;61:750–6.
17 Taiwo OA, Cantley LF, Slade MD, *et al*. Sex Differences in injury patterns among workers in heavy manufacturing. *Am J Epidemiol* 2009;169:161–6.
18 Hooftman WE, van der Beek AJ, Bongers PM, *et al*. Is there a gender difference in the effect of work-related physical and psychosocial risk factors on musculoskeletal symptoms and related sickness absence? *Scand J Work Environ Health* 2009;35:85–95.
19 Saleh SS, Fuortes L, Vaughn T, *et al*. Epidemiology of occupational injuries and illnesses in a university population: a focus on age and gender differences. *Am J Ind Med* 2001;39:581–6.
20 Zwerling C, Sprince NL, Ryan J, *et al*. Occupational injuries: comparing the rates of male and female postal workers. *Am J Epidemiol* 1993;138:46–55.
21 Pollack KM, Cheskin LJ. Obesity and workplace traumatic injury: does the science support the link? *Inj Prev* 2007;13:297–302.
22 Pollack KM, Sorock GS, Slade MD, *et al*. Association between Body Mass Index and Acute Traumatic Workplace Injury in Hourly Manufacturing Employees. *Am J Epidemiol* 2007;166:204–11.
23 Ryan J, Zwerling C, Orav EJ. Occupational risks associated with cigarette smoking: a prospective study. *Am J Public Health* 1992:82:29–32.
24 Chau N, Bhattacherjee A, Kunar BM, Lorhandicap Group. Relationship between job, lifestyle, age and occupational injuries. *Occup Med (Lond)* 2009;59:114–19.
25 Wohl AR, Morgenstern H, Kraus JF. Occupational injury in female aerospace workers. *Epidemiology* 1995;6:110–4.
26 Pollack KM, Agnew J, Slade MD, *et al*. Use of employer administrative databases to identify systematic causes of injury in aluminum manufacturing. *Am J Ind Med* 2007;50:676–86.
27 Vegso S, Cantley LF, Slade MD, *et al*. Extended work hours and risk of acute occupational injury: a case-crossover study of workers in manufacturing. *Am J Ind Med* 2007;50:597–603.
28 Tessier-Sherman B, Galusha D, Taiwo O, *et al*.Further validation that claims data are a useful tool for epidemiologic research on hypertension. *BMC Public Health* 2013;13:51.
29 Goldenhar LM, Swanson NG, Hurrell JJ Jr, *et al*. Stressors and adverse outcomes for female construction workers. *J Occup Health Psychol* 1998;3:19–32.
30 Parker SK, Griffin MA. What is so bad about a little name-calling? Negative consequences of gender harassment for overperformance demands and distress. *J Occup Health Psychol* 2002;7:195–210.
31 Goldenhar LM, Sweeney MH. Tradeswomen's perspectives on occupational health and safety: a qualitative investigation. *Am J Ind Med* 1996;29:516–20.
32 Kelsh MA, Sahl JD. Sex differences in work-related injury rates among electric utility workers. *Am J Epidemiol* 1996;143:1050–8.
33 Hall EM. Gender, work control, and stress: a theoretical discussion and an empirical test. *Int J Health Serv* 1989;19:725–45.
34 Turgoose C, Hall L, Carter A, *et al*. *Encouraging an increase in the employment of women returners in areas of skill shortage in traditionally male industries, 2006*. University of Sheffield, Department of Trade and Industry, and Institute of Work Psychology. http://www.dti.gov.uk/files/file28572.pdf (accessed 31 Aug 2013).
35 Kubo J, Goldstein BA, Cantley LF, *et al*. Contribution of health status and prevalent chronic disease to individual risk for workplace injury in the manufacturing environment. *Occup Envir Med* 2014;71:159–66.
36 Nordander C, Ohlsson K, Balogh I, *et al*. Gender differences in workers with identical repetitive industrial tasks: exposure and musculoskeletal disorders. *Int Arch Occup Environ Health* 2008;81:939–47.
37 Hopcia K, Dennerlein JT, Hashimoto D, *et al*. Occupational injuries for consecutive and cumulative shifts among hospital registered nurses and patient care associates: a case-control study. *Workplace Health Saf* 2012;60:437–44.
38 Pollack K. Chronic diseases and individual risk for workplace injury. *Occup Envir Med* 2014;71:155–6.