RESEARCH ARTICLE

Ergonomic demands and fetal loss in women in welding and electrical trades: A Canadian cohort study

Nicola Cherry MD, PhD[1] | Jeremy Beach MD[1] | Jean-Michel Galarneau PhD[2]

[1]Division of Preventive Medicine, University of Alberta, Edmonton, Alberta, Canada

[2]Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada

Correspondence
Nicola Cherry, 5-22 University Terr, 8303 112 St, Edmonton, Alberta T6G 2T4, Canada.
Email: ncherry@ualberta.ca

Abstract

Objectives: To determine the relationship between ergonomic demands of the job at conception and fetal loss (miscarriage or stillbirth).

Methods: Women with a welding or electrical trade apprenticeship were identified across Canada for the Women's Health in Apprenticeship Trades–Metal and Electrical study. They completed a reproductive and employment history at recruitment and every 6 months for up to 5 years to provide details on pregnancies and work demands. Job at conception was identified and fetal loss examined in relation to ergonomic exposures/demands, allowing for potential confounders.

American Journal of Industrial MedicineResults: A total of 885 women were recruited; 447 in welding and 438 in electrical trades. Of these, 574 reported at least one pregnancy. Analysis of 756 pregnancies since the woman started in her trade suggested no increased risk of fetal loss in those choosing welding rather than electrical work. Among 506 pregnancies conceived during a period working in a trade, 148 (29.2%) ended in fetal loss: 31.2% (73/234) in welding, and 27.6% (75/272) in electrical work. Detailed exposure information was available for 59% (299/506) of these pregnancies. In welders, the risk of fetal loss was increased with whole-body vibration (prevalence ratio [PR] = 2.14; 95% confidence interval [CI] 1.39–3.31) and hand-arm vibration for > 1 hour/day (PR = 2.15; 95% CI 1.33–3.49). In electrical workers risk increased with more than 8 days working without a rest day (PR = 2.29; 95% CI 1.25–4.17). Local exhaust ventilation reduced risk in welders.

Conclusions: There was no significant increase in fetal loss in welding trades compared to electrical work. Vibration, largely from grinding, and extended work rotations appear to be potentially modifiable factors of some importance.

KEYWORDS
electrical trades, pregnancy, vibration, welders, WHAT–ME, women

1 | INTRODUCTION

As women move into work previously carried out mainly by men, there may be justified concern that exposure guidelines based on the experience of male workers may be ill-suited to protect either woman with the same exposures or the fetus if a woman becomes pregnant. Welding is one trade that has raised concerns about pregnancy. Since women have, until recently, entered welding in small numbers, information on pregnancy outcomes has been based on women identified as metal workers or welders in community-based studies.[1–5] Data reported from these studies are consistent with increased risk of spontaneous abortion,[3] low birth weight,[1,2,4,5] and prematurity.[5] Multiple hazards to the fetus may be in play, including substantial ergonomic demands, from the welding itself, the manipulation of heavy components, and the body postures needed to reach parts to be welded. Recent systematic reviews and meta-analyses have supported the role of heavy physical work in poor pregnancy outcomes.[6,7] In Western Canada, much of the demand for welders and other tradespeople has been in the oil fields, with exposure to harsh conditions, including long working schedules implicated in adverse pregnancy outcomes.[8]

In response to a request from the Canadian Standards Association, a protocol was developed to recruit women welders and, as a comparison group, women in the electrical trades. This study, of Women's Health in Apprenticeship Trades–Metal and Electrical (WHAT–ME), was designed to investigate whether work as a welder was associated with adverse pregnancy outcomes and to help identify any exposures responsible. The present paper addresses one outcome, fetal loss (miscarriage or stillbirth), poorly addressed in record linkage or point of delivery studies

2 | METHODS

Preparations to set up cohorts of women in the welding and electrical trades began in 2010, following preliminary work to determine whether such a study would be acceptable to women in the trades and to develop self-report questionnaires that accurately reflected welding tasks.[9] Women entering apprenticeships from 2005 to 2014 in welding (welding, boiler-making, steam fitting, and pipefitting) and electrical (commercial, industrial, or residential) trades were identified by apprenticeship boards (or equivalent) across Canada.[10] The board sent a letter to each apprentice or tradesperson identified, inviting them to complete a consent form and forward it to the research team. Baseline information was collected by telephone or online, in English or French, when the consent form was received. Women were subsequently contacted at 6-month intervals for up to 5 years. Participants were not paid for taking part in the study.

The baseline questionnaire collected demographic and health information, a job history, use of tobacco and alcohol, and details of all pregnancies and births. At each 6-month follow-up, the use of tobacco and alcohol was brought up to date, all jobs since the last contact were recorded and questionnaires were completed about tasks and activities on the last day on which they carried out their trade.

Women were asked to notify us as soon as they became pregnant (with a positive pregnancy test), by phoning a toll-free line, by email, or by sending back a "pregnancy card," a distinctive pre-franked postcard distributed at recruitment and at intervals during the study. Every follow-up questionnaire also asked about pregnancies since the last contact, and a "wrap-up" questionnaire sent at the end of the study, included a question specifically on miscarriages, potentially underreported at the periodic follow-up contacts.

Pregnancy outcomes reported by the participant were: fetal loss (spontaneous abortion or stillbirth) at any gestation, and, for live births, gestation in weeks and birth weight. For those living in Alberta, linkage was made (with consent) to the administrative health database from which dates of physician-consulted miscarriages were retrieved. Stillbirths were found also from the provincial perinatal register. When a woman reported a pregnancy, she was asked to complete two questionnaires (usually in the first and third trimester) and a further one post-pregnancy. The conception date was estimated for each pregnancy, from the date of the last menstrual period where reported on a pregnancy questionnaire, or from reported gestation. Where no gestation data were available for a miscarriage, this was assumed to be at eight weeks (the median length for those with such data). The estimated date of conception was linked to the employment record to determine occupation and exposures close to the time of conception.

Exposures of interest were, for all women, whether or not they were in paid employment at the date of conception and, if they were, whether this was in their trade (welding or electrical work) or elsewhere. For those working in trade at conception, we considered ergonomic demands (hours manipulating heavy objects, standing, crouching, working above shoulder height, driving, working in a noisy, hot or cold job environment, work with tools or equipment causing hand/arm or whole-body vibration, work schedules (hours of work, maximum days worked without a rest day, and number of consecutive nights worked after midnight) and factors influencing respiratory exposure (percentage of time using a respirator, working with general mechanical ventilation, local exhaust ventilation (LEV), outdoors, or in a confined space). Six participants had missing information on the perceived intensity of heat, cold, and noise: for those with missing values ratings were estimated from the median intensity of those with the same hours of exposure.

An example of the follow-up questionnaire used for welders is included as Appendix A and information on the construction of exposure variables in Appendix B.

2.1 | Statistical methods

Differences between those in the welding and electrical trades in baseline characteristics and pregnancy outcomes were evaluated by χ^2 tests. Mean differences in exposures were examined by analysis of variance. The effects of exposures at conception were estimated in multilevel Poisson models with robust standard errors, allowing for more than one conception for each participant (clustering) and

adjusting for confounders. Where the Poisson model failed to converge an estimate was made (and noted) using a logistic model. Exposures were considered either as continuous factors (hours, percentage of time, rating of noise, heat, and cold) or as categorical variables. For this they were grouped first into approximate tertiles, using the closest whole unit as the breakpoint, and the lowest tertile of exposure used as the comparison group. The tertiles were collapsed to binary factors for later analyses. Where less than a third had been exposed, the binary (any/none) grouping was used throughout. Potential confounders were age, number of previous pregnancies, number of cigarettes smoked per day, number of alcoholic drinks per week, and body mass index (BMI), all considered as continuous variables. A history of previous fetal loss was entered as a binary factor. All were evaluated at the estimated date of conception of each pregnancy. Exposure factors and potential confounders were considered for the final model if they reached a significance level of $p < 0.10$ in bivariate analyses. Wald statistics were computed to arrive at the final model with systematic inclusion/exclusion of variables to determine the final selection, with $p < 0.05$ for the variables included. Analysis was carried out in STATA 14.2

3 | RESULTS

The first recruitment questionnaire was completed on January 8, 2011 and the last on September 24, 2017. Follow-up continued until August 27, 2018.

The recruitment questionnaire was completed by 447 women in welding and 438 in electrical trades. Of these 96.5% (854/885) filled out at least one follow-up questionnaire, with a mean of 7.5 questionnaires per respondent. Women who had entered a welding apprenticeship completed fewer questionnaires (mean 7.0) than women in the electrical trades (mean 8.2) ($p < 0.001$). Women were recruited from all Canadian provinces, the Yukon and the North West Territories but with the majority 58.3% (516/885) from Alberta.

Of the 885 women, 574 (64.9%) reported at least one pregnancy since leaving high school: 60 high school pregnancies contributed to gravidity but were not considered further. The average number of pregnancies in these gravid women was 2.3 (range 1–9), a total of 1346 pregnancies. Of these, 219 ended in elective abortion, 15 were terminated as ectopic pregnancies and the outcome of three pregnancies was unknown. Many of the 1109 pregnancies with known
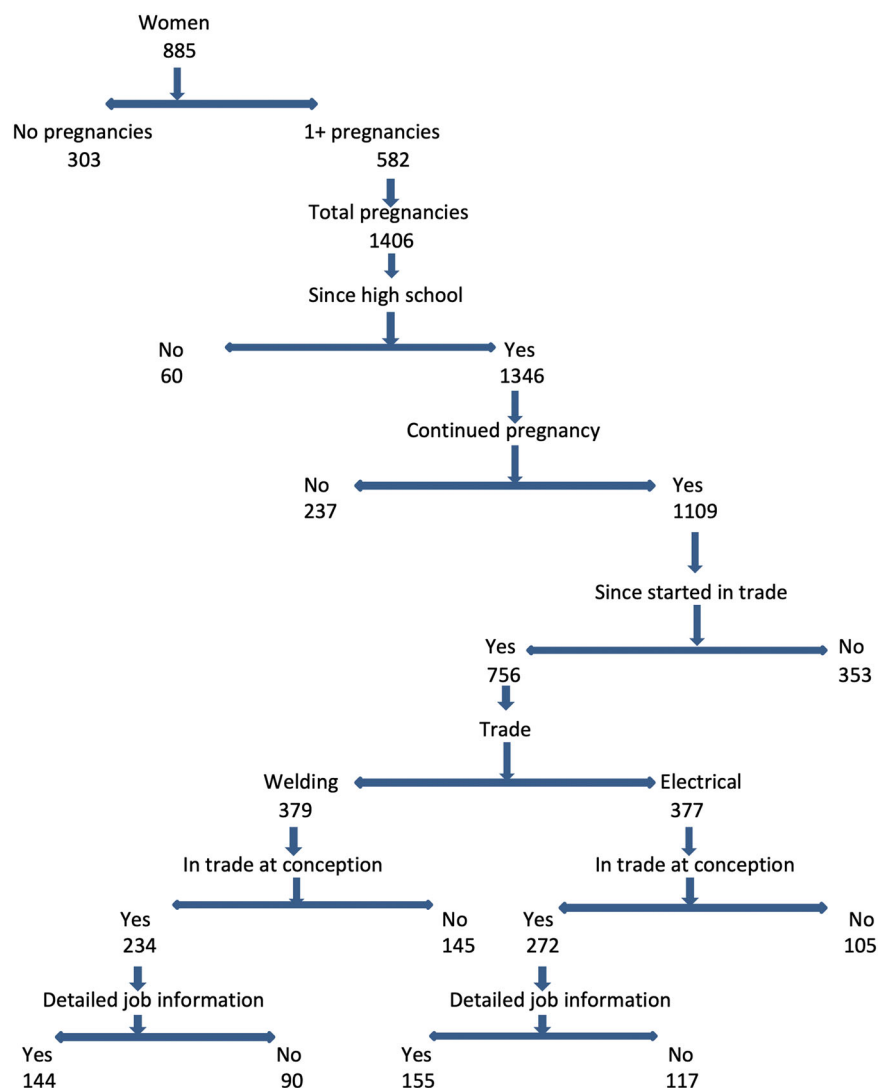
FIGURE 1 Flow chart of pregnancies in welders and electricians in Women's Health in Apprenticeship Trades–Metal and Electrical (WHAT–ME)

	Welding		Electrical		Both		
	N	%	N	%	N	%	p*
Age							
≤25	74	35.9	40	22.1	114	29.5	0.013
26–35	109	52.9	108	59.7	217	56.1	
36–45	15	7.3	24	13.3	39	10.1	
≥46	8	3.9	9	5.0	17	4.4	
Pregnancy (not terminated) before trade							
Yes	31	15.0	22	12.2	53	13.7	0.460
No	175	85.0	159	87.8	334	86.3	
Body Mass Index							
<25	118	57.3	92	50.8	210	54.3	0.443
25 < 30	61	29.6	61	33.7	122	31.5	
≥30	27	13.1	28	15.5	55	14.2	
Cigarette smoking							
None	142	68.9	154	85.1	296	76.5	0.001
<10/day	26	12.6	14	7.7	40	10.3	
≥10/day	38	18.4	13	7.2	51	13.2	
Drinking alcohol							
None	72	35.0	60	33.0	132	34.1	0.087
<7/week	102	49.5	105	58.0	207	53.5	
7 or more/week	32	15.5	16	8.8	48	12.4	
N	206	100.0	181	100.0	387	100.0	

TABLE 1 Characteristics at recruitment of women who conceived after joining their trade

outcomes, not electively terminated, were before the woman started in her trade (N = 353) and many more (N = 250) were conceived during periods when she was either not in paid employment or working outside her trade (Figure 1). Detailed job information was available for 299 women working in their trade at the time of conception.

Demographic factors at recruitment of the 387 women with one or more of the 506 included pregnancies since joining their trade are shown in Table 1. Women in welding were younger at recruitment than those in the electrical trades, more likely to smoke cigarettes and, if they drank alcohol, to report rather more drinks per week. Pregnancies since started in a trade that ended in miscarriage or stillbirth (fetal loss) are shown in Table 2. In this unadjusted analysis, there was a little evident difference in outcome for those recruited from the welding and electrical trades. Fetal loss was not more common among those working in their trade, but all eight stillbirths among these 756 pregnancies were conceived while the woman was in her trade, five in welders, three in electricians. The relation of potential confounders to outcome is shown in Table 3 for welders and those in electrical work in their trade at conception. Age, smoking cigarettes, the number of previous pregnancies, and a previous fetal loss were retained as potential confounders for the analysis of in-

trade pregnancies. In a multivariable analysis of Table 2, allowing for clustering within women, work status, and potentially confounding factors from Table 3, no overall difference in risk of fetal loss was found between women entering the welding and electrical trades, among the 756 women who conceived after entering the trade (odds ratio [OR] for welder = 1.09 95% confidence interval [CI] 0.88–1.35).

The means of the 18 dimensions of work for in-trade pregnancies in welders and electrical workers are shown in Table 4. Those in welding spent more time than those in electrical work manipulating heavy objects, standing, and exposed to whole body and hand/arm vibration. They were also more likely to report wearing a respirator and working with general mechanical ventilation and to work in noisy and hot jobs. Those in the electrical trades spent more time crouching or kneeling down. The relation of fetal loss to each exposure is shown as a crosstabulation in Table 5 which includes only factors that showed some relation (p < 0.10), in at least one trade group, to fetal loss. After adjustment for clustering, only long hours of work (>10 h), work in confined space or in a colder job and a job requiring long rotations without a rest day (maximum > 8 days) were associated with an increased risk of fetal loss for those in the electrical trades (Table 6). Working in an environment with consistent general mechanical ventilation decreased risk. Among welders, the use of tools

TABLE 2 Pregnancy outcomes since joining trade, by trade, and work status at conception

Work status	Welding		Electrical		Both		p*
	N	%	N	%	N	%	
Fetal loss							
Not working							
Live birth	64	66.0	52	73.2	116	69.0	
Fetal loss	33	34.0	19	26.8	52	31.0	0.399
Total	97	100.0	71	100.0	168	100.0	
Working, not in trade							
Live birth	32	66.7	18	52.9	50	61.0	0.254
Fetal loss	16	33.0	16	47.1	32	39.0	
Total	48	100.0	34	100.0	82	100.0	
Working in trade							
Live birth	161	66.8	197	72.4	358	70.8	
Fetal loss	73	31.2	75	27.6	148	29.2	0.380
Total	234	100.0	272	100.0	506	100.0	
All pregnancies							
Live birth	257	67.8	267	70.8	524	69.3	0.386
Fetal loss	122	32.2	110	29.2	232	30.7	
Total	379	100.0	377	100.0	756	100.0	

*p value from a χ^2 test.

TABLE 3 Potential confounders for fetal loss for welders in trade, electricians in trade, and all in trade

	Welders		Electrical work		Both	
	PR	95% CI	PR	95%CI	PR	95% CI
Age	1.03	0.99–1.07	1.04*	1.00–1.09	1.03*	1.00–1.07
BMI	1.01	0.95–1.06	1.03	0.99–1.08	1.02	0.99–1.06
Number of cigarettes per day	1.02	1.00–1.05	1.03	0.99–1.07	1.03*	1.00–1.05
Number of alcoholic drinks per week	1.01	0.98–1.05	0.98	0.90–1.06	1.00	0.97–1.04
Number of previous pregnancies	1.20*	1.08–1.34	1.19*	1.05–1.34	1.20*	1.10–1.30
Previous fetal loss						
No	1	–	1	–	1	–
Yes	1.62*	1.11–2.36	2.98**	1.47–6.04	1.85*	1.40–2.44
N:						
Pregnancies	234		272		506	
Women	158		167		325	

Abbreviations: CI, confidence interval; PR, prevalence ratio.

*$p < 0.10$ and included as a potential confounder.

**Estimate from logistic model: Poisson did not converge.

or equipment resulting in any whole-body vibration or hand-arm vibration for >1 h/day were both associated with an increased risk of fetal loss as was manipulating heavy objects for at least 1.5 h/day. Any use of local exhaust ventilation, reported by only 16.0% of these welders, reduced risk. When both trades were considered together, long hours of work, work in a colder job, long rotations without a rest day and use of equipment or tools causing hand-arm vibration were associated with fetal loss, after allowance for clustering.

Final models, adjusting for confounders where these contributed significantly ($p < 0.05$) to the model, are given in Table 7. In welders,

TABLE 4 Work exposures by trade: In-trade pregnancies

	Welding trades		Electrical trades		Both		
	Mean	SD	Mean	SD	Mean	SD	p*
Hours working last day at work	9.19	2.18	9.34	1.79	9.27	1.99	0.507
Hours manipulating heavy objects	1.23	1.82	0.93	1.54	1.07	1.69	0.127
Hours standing	6.33	2.89	5.48	2.61	5.89	2.78	0.008
Hours working above shoulder height	1.73	2.82	1.93	2.22	1.84	2.52	0.501
Hours crouching or kneeling	1.72	2.15	2.40	2.00	2.07	2.10	0.005
Hours with whole-body vibration	0.15	0.77	0.01	0.09	0.08	0.54	0.027
Hours with hand/arm vibration	1.78	2.73	0.65	1.55	1.19	2.27	<0.001
Hours driving	0.33	0.94	0.31	0.97	0.32	0.95	0.876
Maximum length of rotation (days)	10.49	11.90	9.95	10.00	10.21	10.94	0.668
Maximum nights after midnight	1.08	2.86	1.06	2.60	1.07	2.72	0.953
% of time using respirator	27.09	38.37	8.32	22.65	17.36	32.56	<0.001
% of time with general ventilation	52.76	45.42	38.08	43.23	45.15	44.83	0.005
% of time using local exhaust ventilation	8.14	21.48	7.78	22.73	8.00	22.10	0.889
% of time outdoors	26.45	41.69	26.88	38.89	26.68	40.19	0.926
% of time in a confined space	4.52	18.36	6.10	20.60	5.34	19.54	0.488
Rating** of noisiest job	6.82	2.67	4.61	2.66	5.67	2.88	<0.001
Rating** of hottest job	4.35	2.82	3.37	2.71	3.84	2.80	0.002
Rating** of coldest job	2.94	2.89	2.95	2.75	2.95	2.81	0.958
N	144		155		299		

Abbreviation: SD, standard deviation.

*p value from an analysis of variance, comparing means between trades.

**Rating on a scale from 1–10.

the fetal loss was more likely in those reporting whole body and hand-arm vibration and less likely in those reporting they used local exhaust ventilation. In the electrical trades, the final model for fetal loss showed increased risk with more than 8 days of work without a rest day, with greater cold intensity and with previous fetal loss. For the two trades together, risk of fetal loss was higher where the woman worked in a job that entailed extended days of work without a break, reported hand-arm vibration, and with a previous history of fetal loss. In this model, work as a welder carried no more risk of fetal loss (OR = 0.87 95% CI 0.61–1.24) than work in the electrical trades.

4 | DISCUSSION

The study reported here was designed to establish whether pregnancy outcomes were worse than expected in women who conceived while working in the welding trades and to determine factors that might be responsible. Overall, the results for fetal loss did not suggest the worst outcome in welding than in the comparison group of women entering the electrical trades.

The strength of the study lies in the repeated measures prospective design, in which information about work demands around the time of conception was collected before the outcome of the pregnancy was known. Where this did not happen as planned, this was also a weakness: when a woman sustained an early miscarriage, exposure estimates were taken from whichever questionnaires described the job at conception. If this was collected post-event, the possibility of reporting bias cannot be excluded. The design did, however, give confidence that very few pregnancies were missed completely and the quality of the information on numbers, dates, and outcomes of pregnancies is likely to be higher than in a retrospective design. Moreover, it allowed analysis of miscarriages using near-contemporary exposure data. Although the level of collaboration was high in those recruited, those who took part may have been unrepresentative of all women in these trades. Estimates suggest a take-up rate of at most 15% of tradeswomen[10] and this limits the extent to which results can be generalized.

The power of the study depended on the number of conceptions in-trade since joining the study. The number of elective terminations, and of women leaving their trade, reduced the numbers contributing to key analyses. The wealth of data on in-trade pregnancies allowed

TABLE 5 Relation of fetal loss to ergonomic exposures by trade unadjusted for clustering of pregnancies within women: In-trade conceptions

	Welder				Electrical				Both			
	Fetal loss	N	% fetal loss	p (x^2)	Fetal loss	N	% fetal loss	p (x^2)	Fetal loss	N	% fetal loss	p (x^2)
Hours of work												
≤10	17	81	21.0	0.127	18	92	19.6	0.016	35	173	20.2	0.004
≥10	21	63	33.0		24	63	38.1		45	126	35.7	
Night after Midnight												
≤3	30	123	24.4	0.192	34	137	24.8	0.093	64	260	24.6	0.051
≥3	8	21	38.1		8	18	44.0		16	39	41.0	
Maximum days												
≤8	21	90	23.3	0.330	16	101	15.8	<0.001	37	191	19.4	<0.001
>8	17	54	31.5		26	54	48.1		43	108	39.8	
Whole-body vibration												
None	32	133	24.1	0.067	42	152	27.6	0.563	74	285	26.0	0.213
Some	6	11	54.6		0	3	0.0		6	14	42.9	
Hand-arm vibration												
1 h or less	18	92	19.6	0.018	33	132	25.0	0.203	51	224	22.8	0.010
>1 h	20	52	38.5		9	23	39.1		29	75	38.7	
Manipulate heavy objects												
<1.50 h	21	105	20.0	0.007	36	125	28.8	0.522	45	205	22.0	0.007
≥1.50 h	17	39	43.6		6	30	20.0		35	94	37.2	
Hours confined space												
None	36	132	27.3	0.733	33	138	23.9	0.019	69	270	25.6	0.185
Some	2	12	16.7		9	17	52.9		11	29	37.9	
Hours general ventilation												
<100%	20	85	23.5	0.442	37	112	33.9	0.008	57	197	28.0	0.271
100%	18	59	30.5		5	43	11.6		23	102	22.5	
Hours with local exhaust ventilation												
None	36	121	29.8	0.040	34	134	25.4	0.290	70	255	27.5	0.584
Some	2	23	8.7		8	21	38.1		10	44	22.7	
Coldest rated												
1	24	90	26.7	1.000	15	83	18.1	0.011	39	173	22.5	0.064
>1	14	54	25.9		27	72	37.5		41	126	32.5	
N pregnancies	38	144			42	155			80	299		

the identification of risks associated with specific exposures, rather than simply an analysis of risk by job title or exposures inferred from the title. There are limitations also in the exposure assessment. Psychological stressors, which form part of ergonomic demands widely drawn, are not considered here and the exposures estimates reflect largely the time reported doing tasks rather than an attempt to estimate the energy expenditure required. This makes comparison with other studies more difficult.

Studies of miscarriage are difficult as there is no comprehensive database for such events, and as such this outcome cannot be adequately investigated through record linkage. Information is best collected prospectively from the woman herself. Very early miscarriage, before a pregnancy is recognized, cannot be investigated by this study design except, perhaps, in a time-to-pregnancy analysis. Earlier data on fetal loss in these trades comes from a study of previous pregnancy outcomes among

TABLE 6 Relation of fetal loss to exposures: Bivariate Poisson regression allowing for clustering

	Welding		Electrical		Both	
	PR	95% CI	PR	95% CI	PR	95% CI
Hours of work						
<10	1	–	1	–	1	–
≥10	1.59	0.88–2.87	1.93*	1.05–3.54	1.77*	1.15–2.71
Night after midnight						
≤3	1	–	1	–	1	–
>3	1.56	0.81–3.02	1.75	0.64–4.78	1.97	0.65–6.01
Maximum days						
≤8	1	–	1	–	1	–
>8	1.35	0.76–2.40	7.49**	2.07–27.18	2.06*	1.36–3.12
Whole-body vibration						
None	1	–	1	–	1	–
Some	2.27*	1.25–4.12	Did not converge		1.65	0.83–3.26
Hand-arm vibration						
1 h or less	1	–	1	–	1	–
>1 h	1.97*	1.15–3.36	1.50	0.60–3.76	1.70*	1.09–2.65
Manipulate heavy objects						
<1.50 h	1	–	1	–	1	–
≥1.50 h	2.18*	1.29–3.70	0.71	0.30–1.66	1.34	0.85–2.14
Hours confined space						
None	1	–	1	–	1	–
Some	0.98	0.97–1.00	1.01*	1.00–1.02	1.00	0.99–1.01
Hours general ventilation						
<100%	1	–	1	–	1	–
100%	1.30	0.74–2.29	0.36*	0.13–0.96	0.78	0.49–1.25
Hours with local exhaust ventilation						
None	1	–	1	–	1	–
Some	0.29*	0.08–1.10	1.42	0.49–4.14	0.81	0.32–2.03
Rating of coldest job	1.01	0.90–1.13	1.15*	1.06–1.26	1.08*	1.01–1.16
N pregnancies	144		155		299	
N women	108		109		217	

Abbreviations: CI, confidence interval; PR, prevalence ratio.

*$p < 0.10$ with adjustment for clustering and contribution assessed for final model.

**Estimate from a logistic model. Poisson did not converge.

56,067 women interviewed immediately after delivery or spontaneous abortion in Montreal Canada.[3] Women in the metal and electrical sectors had an increased risk of spontaneous abortion or stillbirth, with 150 such outcomes in 535 pregnancies (28.0%). The rates of fetal loss in women working in their trade (31.2% in welders, 27.6% in the electrical trades) in the current study are close to the combined rate in these trades reported by McDonald and colleagues.[3]

Systematic reviews support a role for heavy or frequent occupational lifting[6,7] on miscarriage. In this study we asked how much of the time the participant used to lift, push, pull, or otherwise manipulate heavy materials or goods, thus covering a wider range of physical effort than simply lifting. There was an increase in risk for welders with hours of manipulating heavy goods, but this was not sustained after adjustment for other exposures (vibration). For those in electrical work the strongest single predictor of fetal loss was

TABLE 7 Exposures associated with fetal loss by trade: Women in trade at time of conception

	Welding			Electrical			Both		
	PR	95% CI	p	PR	95% CI	p	PR	95% CI	p
Exposure									
Welder							0.87	0.61–1.24	0.427
Longest rotation more than 8 days				2.29	1.25–4.17	0.007	1.75	1.18–2.60	0.006
Hand-arm vibration	2.15	1.33–3.49	0.002				1.55	1.07–2.25	0.020
Any whole-body vibration	2.14	1.39–3.31	0.001						
Any local exhaust ventilation	0.25	0.07–0.89	0.032						
Cold intensity rating				1.09	1.01–1.17	0.023			
Previous fetal loss				1.73	1.08–2.79	0.023	1.69	1.19–2.41	0.003
N pregnancies	144			155			299		
N women	108			109			217		

Abbreviations: CI, confidence interval; PR, prevalence ratio.

working 8 or more days without a rest day. This was a stronger predictor than long hours of work or working night shifts, factors identified by systematic review as related to miscarriage.[8] Long rotations are a feature of trade work in more remote parts of Canada, with tradespeople working for many days before returning to a home base. We are not aware of others identifying this as a risk for fetal loss, but the fatigue generated may be similar to, or surpass, that of working long hours in a single workday.

In the present study, vibration, which arose largely from the use of grinding tools, was associated with fetal loss in welders. Vibration was included as a risk factor by McDonald and colleagues[3] in their study of fetal loss and found to relate particularly to an increase in late abortions and stillbirths. Whole-body vibration, assigned by a job exposure matrix, has recently been reported, from Sweden, to relate to preterm birth but not low birthweight,[11] with similar findings, using self-report of vibration exposure, in Nigeria[12] and Canada.[13] The observed protective effects of consistent mechanical ventilation for those in the electrical trades and of local exhaust ventilation in welders, flags up the need for wider implementation, but we cannot rule out the possibility that these may be markers for a particular type of task or employer (e.g., one willing to invest in the safety of the worker) rather than necessarily a direct effect of a reduced concentration of airborne contaminants toxic to the fetus.

The choice of electrical workers as the comparison group was made deliberately to minimize the likelihood that any excess of poor pregnancy outcomes in welders resulted from inadequate adjustment for confounding. Both groups of tradeswomen were doing physically demanding jobs and use of other tradeswomen as the comparison recognizes that the lifestyles of women choosing to go into the trades may differ importantly from women making more conventional career choices. We have found no difference in the rate of fetal loss for women working in the welding and electrical trades, but both trades entail ergonomic demands that should be addressed to reduce the risk of fetal loss for women working in their trade.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

ETHICS APPROVAL AND INFORMED CONSENT

The project was reviewed by the Health Ethics Review Board of the University of Alberta (Pro00017851). All participants gave written informed consent.

AUTHOR CONTRIBUTIONS

The project was conceived by Nicola Cherry and Jeremy Beach and data collected under their guidance. The analysis was carried out by Jean-Michel Galarneau and Nicola Cherry. Nicola Cherry drafted the final report which was critically reviewed and amended by all authors. All have approved the final version and agree to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

DISCLAIMER

None.

ORCID

Nicola Cherry http://orcid.org/0000-0002-3147-1548

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APPENDIX B: CONSTRUCTION OF ERGONOMIC VARIABLES TO INCLUDE MULTIPLE TASKS

Information on job tasks was collected from sub-routines of questions relating to each task (see the questionnaire at Appendix A). The sub-routine information was summarized for analysis as follows:

a. Time standing

    Each sub-routine included questions on standing, walking, and standing while leaning over an object and time in those positions computed. Ax there was considerable overlap, the longest time among the three was chosen to represent stand time in that sub-routine. Time standing was then cumulated across all sub-routines.

b. Time lying down, time standing while crouching over objects, time sitting

    The amount of time in these positions was individually computed by adding up the time reported in each position across all sub-routines.

    Both **a** and **b** were adjusted when their sum exceeded the work hours from that day by more than 30 min. This was done by calculating a time representing the cumulative amount of time spent in all positions considered exclusive, that is, time standing, time lying down, standing while crouching over an object, and seating. If this exclusive time exceeded what was possible for that work day then the following adjustments were made equally for both **a** and **b**:

    (Working hours/exclusive time working) × ergonomic position from **b** and **c**.

c. Time spent lifting or pushing heavy objects, time spent with whole-body vibration

    These variables were derived by taking the longest lifting/pushing heavy objects (or whole-body vibration) time across sub-routines as the measure for that ergonomic position. If that ergonomic position exceeded the working hours of that day by more than 30 min, it was adjusted as shown above.

d. Time spent working with arms above shoulders, time spent working with hand-arm vibration, time spent driving

    These were calculated by summing up all of the time spent working with arms above shoulders (or time working with hand-arm vibration, or time driving) across all sub-routines and adjusting as shown above if that time exceeded working hours by more than 30 min.

e. Maximum days worked consecutively

    This was reported at every follow-up that included a work period since the last questionnaire. Participants were asked the number of days worked consecutively without taking a break.

f. Work after midnight, number of nights working after midnight consecutively

    Information on the number of consecutive night shifts was gathered at every follow-up.

g. Time working outdoors, time working in a confined space, time working with respiratory equipment, time working with mechanical ventilation, time working with local exhaust ventilation

These variables were all derived as proportion of time spent working in such conditions. For the time spent working outdoor and in a confined space, this was asked in each sub-routine as a proportion which was multiplied by the time working in that sub-routine. This was then summed up across sub-routines and divided by the total number of hours across all sub-routines giving an overall proportion of time working outdoors or in a confined space. For respiratory protection, ventilation and local exhaust ventilation, the questions were asked if they worked under these conditions always, sometimes or never. Always was therefore taken as 100% of the time, sometimes as 50% of the time and never as 0% of the time. The proportions were then used in the same way as the proportions for working outdoors and in a confined space.

h. Ratings on a scale from 1 to 10 of the noisiest, hottest, coldest job done on the most recent day at work