Original research

Association between maternal occupation as a cleaner/maid/janitor during early pregnancy and selected birth defects in the National Birth Defects Prevention Study

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ABSTRACT

Objectives Cleaning work involves potential exposures to physical, chemical, biological and psychosocial hazards, which might increase the risk of birth defects. Yet, there is limited research focused on maternal occupation in cleaning jobs and the risk of birth defects. We investigated the association between maternal occupation in cleaning-related jobs during early pregnancy and selected birth defects in the National Birth Defects Prevention Study, a case–control study from 1997 to 2011.

Methods Mothers self-reported job details, which were classified by occupational epidemiologists into cleaner or non-cleaner occupations. Cases were live births or stillbirths with at least one of 19 eligible birth defects ascertained from state surveillance systems, while controls were randomly selected live births without structural defects. We estimated adjusted ORs with 95% CIs from multivariable logistic regression for associations between maternal cleaning occupations and birth defects, controlling for eight covariates identified a priori.

Results Of the 28 936 mothers, 1109 (868 cases/241 controls) were assigned a primary occupational code as a cleaner during early pregnancy. In total, 9 of the 19 included birth defects had elevated ORs (>1.5), ranging from 1.58 for anophthalmia/microphthalmia to 2.65 for oesophageal atresia/stenosis; six had CIs that excluded the null (anencephaly, glaucoma, anotia/microtia, cleft lip and palate, oesophageal atresia/stenosis, small intestinal atresia/stenosis).

Conclusions We observed that maternal occupation in cleaning-related jobs was associated with several specific birth defects in various body systems. Future studies should explore specific chemical and physical exposures under these cleaning occupations and the association with birth defects.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Cleaning-related occupations involve multiple workplace exposures; however, the potential associations between these occupations and risks of birth defects are underexplored.

WHAT THIS STUDY ADDS

⇒ This study observed that maternal occupation in cleaning-related jobs during early pregnancy was associated with increased risks of certain birth defects across several organ systems.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings emphasise the need for future research on occupational exposures in pregnancy. The results can also increase awareness of workplace safety and inform policies on public health interventions to minimise reproductive risks for cleaning workers.

INTRODUCTION

Those working in cleaning occupations, including maids and janitors, play significant roles in maintaining hygiene and sanitation in various settings such as schools, hospitals, offices and homes. In 2023, more than 3.6 million individuals were employed as janitors or maids nationwide, and approximately one-third of the cleaning workforce are females of reproductive age.[1 2] As part of their cleaning work, workers are potentially exposed to physical, chemical, biological and psychosocial stressors, which may be particularly hazardous to their reproductive health and could result in adverse pregnancy outcomes.[2–4] While moderate physical activity may be beneficial to pregnant women, the highly physical duties in cleaning work, such as prolonged standing, awkward postures and lifting/carrying heavy objects, can contribute to circulation issues and/or injuries and potentially account for intrauterine growth restriction and other adverse birth outcomes.[5] Those in cleaning occupations frequently work with a range of solvents that may contain volatile organic compounds (VOCs) and endocrine-disrupting chemicals (EDCs).[6] These substances might significantly disrupt cellular processes and interfere with hormonal functions throughout fetal development. Previous studies have observed positive associations between exposure to cleaning solvents during early pregnancy and birth defects, including neural tube defects (NTDs) and orofacial clefts.[7 8] Additionally, individuals working in cleaning jobs in public settings are more

often exposed to biological hazards such as bacteria, viruses and fungi, which can lead to adverse pregnancy outcomes, including miscarriages, stillbirths and birth defects.[6 9] Moreover, psychosocial factors such as job insecurity, irregular working hours and low wages have been associated with preterm birth.[10]

Although cleaning occupations involve significant hazards, studies specifically investigating the associations between these cleaning jobs and adverse pregnancy outcomes, especially birth defects, are scarce. Prior studies using earlier data from the National Birth Defects Prevention Study (NBDPS) analysed a broad range of occupations and found significantly increased risks between maternal occupation in a cleaning job and several birth defects, including neural tube defects, oral clefts and oesophageal atresia.[11 12] A Dutch study observed an elevated risk for spina bifida among infants whose mothers worked in a cleaning occupation in 1996.[13] Moreover, a case–control study found that women exposed to solvents in early pregnancy and those who worked in cleaning occupations had an increased risk of having an offspring with oral clefts.[14] While prior studies explored many specific occupations and their associations with birth defects, few focused specifically on those in cleaning jobs and the duties they perform. We included birth defects that were observed to be associated with cleaning occupations in previous NBDPS publications.[11 12] This study aims to investigate the association between working in a cleaning job and working as a maid or janitor, more specifically, during early pregnancy and the risk of specific birth defects among the offspring, using the complete study population from NBDPS encompassing pregnancies from 1997 to 2011.

METHODS

The NBDPS is a large population-based, multisite, case–control study of major structural birth defects conducted in 10 study sites (Arkansas, California, Iowa, Georgia, Massachusetts, New Jersey, New York, North Carolina, Texas and Utah) and included pregnancies with estimated delivery dates between 1 October 1997 and 31 December 2011. The methods of NBDPS have been described elsewhere.[15 16] Briefly, live births, stillbirths or terminated pregnancies with at least one major structural birth defect ('cases') were ascertained from birth defects surveillance systems in each participating state. Clinical geneticists determined eligibility and classified cases as isolated (ie, a single major defect or organ system involved), multiple (ie, two or more unrelated birth defects occurring in different organ systems) or complex (ie, groups of defects believed to be pathogenetically related, but for which the primary defect is not apparent).[17] Cases diagnosed with a known chromosomal or single-gene abnormality were excluded. Liveborn infants without major structural birth defects ('controls') were randomly selected from the birth certificates or birth hospitals in the same year and study site as cases.

Mothers of cases and controls completed a computer-assisted telephone interview between 6 weeks and 2 years after the estimated delivery date. A group of female interviewers conducted the interviews in English or Spanish, covering a range of topics including past pregnancies, health and diet, medication history, occupation and lifestyle factors during the 3 months before conception through the end of pregnancy. Mothers of cases and controls provided informed consent, and the institutional review board from each study site and the Centers for Disease Control and Prevention approved the protocols of the NBDPS, where applicable.

Mothers self-reported job details for each job held from 3 months before conception through the end of pregnancy, and the number of hours worked during 1 month before conception through the first 3 months of pregnancy ('early pregnancy'). Information on jobs included a narrative description of their company name, what the company makes or does, their job title, their typical job duties and any equipment or chemicals they use. A separate team of occupational epidemiologists and industrial hygienists, blinded to case–control status, assessed and classified reported jobs using the 2000 Standard Occupational Classification System (SOC) codes for occupation and the 1997 North American Industry Classification System (NAICS) codes for industry. Jobs identified as a homemaker or student were not assigned SOC/NAICS codes and were excluded from the analysis.

As was done in previous NBDPS analyses of cleaning occupations,[11 12] we classified mothers as having a cleaning job (hereafter referred to as a 'cleaner') if the primary occupation for any job reported during early pregnancy was assigned one of the following SOC codes: 37–1011 (first-line supervisor/managers of housekeeping and janitorial workers), 37–2010 (building cleaning workers), 37–2011 (janitors and cleaners, except maids and housekeeping cleaners), 37–2012 (maids and housekeeping cleaners), 37–2019 (building cleaning workers, all other) and 53–7061 (car cleaners). We further classified mothers who had a primary SOC code in cleaner occupations into subgroups, which included 'maids' (SOC code 37–2012); 'janitors' (SOC code 37–2011); and 'other cleaners' (SOC codes 37–1011, 37–2010, 37–2019 and 53–7061). Those whose primary job was not cleaning-related but who had a secondary SOC code in a cleaning job (such as cashiers and retail salespersons) were grouped as having a 'secondary code as a cleaner'. Finally, we created an exposure group for mothers whose primary or secondary SOC code did not indicate they were cleaners but who reported performing cleaning duties ('cleaning tasks', such as food service workers and health aides). We considered those who were employed but did not work in cleaning occupations or perform cleaning tasks as part of their job as unexposed (hereafter referred to as 'non-cleaners'). Four mothers held more than one type of cleaning job during early pregnancy and were included in each group. We analysed 19 specific birth defects: central nervous system defects (spina bifida, anencephaly, encephalocele, cerebellar hypoplasia, Dandy-Walker malformation, holoprosencephaly, hydrocephaly), eye defects (anophthalmia/microphthalmia, cataracts, glaucoma), ear defects (anotia/microtia), orofacial clefts (CLP-cleft lip with palate, CL-cleft lip only, CP-cleft palate only), gastrointestinal defects (anorectal atresia/stenosis, duodenal atresia/stenosis, oesophageal atresia/stenosis, small intestinal atresia/stenosis) and amniotic band syndrome.

We conducted descriptive analyses among all mothers and among controls across demographic variables. We also conducted univariate analysis to describe work characteristics among mothers who reported cleaning work. We used logistic regression to estimate the ORs and 95% CIs for each birth defect among those reporting early pregnancy work as a cleaner, and each cleaning subgroup. Women categorised as non-cleaners were the referent group for all analyses. We calculated adjusted ORs (aORs) and 95% CIs for birth defects with five or more exposed cases, controlling for covariates identified a priori based on literature review and hypothesised causal pathways in a directed acyclic graph (online supplemental figure S1): maternal age at delivery, race/ethnicity, educational attainment, early pregnancy smoking status, prepregnancy body mass index, folic acid-containing supplementation during the month before through the first month of pregnancy, number of previous pregnancies

and study site. For defects with three or four exposed cases, we calculated unadjusted ORs and exact 95% CI. We did not calculate estimates of association for defects with fewer than three exposed cases. We did not include the cleaning subgroup of 'other cleaners' in the logistic regression analyses due to the small numbers of exposed cases.

To explore the robustness of our findings, we ran two sensitivity analyses. In one, we restricted to cases with isolated birth defects. In the second, we restricted the analysis to those mothers who reported working at least 40 hours per week during early pregnancy. For both sensitivity analyses, we restricted the analytic set as described and re-ran the multivariable logistic regression model from the main analysis.

RESULTS

The analysis included 21 138 cases and 7798 controls who reported a job during early pregnancy. Overall, 1109 mothers were assigned a primary occupational code as a cleaner during early pregnancy (868 cases/241 controls). Of these, 868 mothers were further classified as maids (677 cases/191 controls), 179 as janitors (138 cases/41 controls) and 66 as another type of cleaners (57 cases/9 controls). We also analysed 241 mothers with a secondary code as a cleaner (181 cases/60 controls) and 1351 mothers who reported performing cleaning tasks but were not considered cleaners (980 cases/371 controls). Finally, our analysis included 19 109 cases and 7126 controls who were employed in non-cleaning occupations.

Among controls, cleaners were younger than non-cleaners: 10.8% of cleaners were less than 20 years old compared with 5.5% of non-cleaners (table 1). Cleaners and non-cleaners had different racial/ethnic distributions among controls: non-Hispanic white mothers were the largest race/ethnicity group among non-cleaners (65.7%), while Hispanic mothers represented the highest proportion among cleaners (40.3%). Among controls, cleaners more frequently reported lower educational attainment, less alcohol use, more cigarette smoking and higher folic acid supplementation during early pregnancy than non-cleaners.

Among cleaners, 21% held more than one job during early pregnancy (table 2), which was significantly higher than non-cleaners (9.8%). Nearly two-thirds of cleaners worked less than 40 hours per week in their cleaning job, which was consistent for both the maid and janitor subgroups, compared with approximately 43.1% of non-cleaners. The most frequently reported task performed by cleaners was sweeping and mopping floors (24%), followed by cleaning bathrooms (23.1%) and vacuuming floors (16.2%). The majority of cleaners worked in the following industries: accommodation and food services (34.6%), administrative and support and waste management and remediation services (34.4%), and healthcare and social assistance (13.3%). Top industries by specific cleaning occupation subgroup are in online supplemental table S1.

Among mothers who worked as a cleaner, we observed that 9 of the 19 studied birth defects had elevated aOR (above 1.50): anencephaly, Dandy-Walker malformation, holoprosencephaly, anophthalmia/microphthalmia, glaucoma, anotia/microtia, CLP, oesophageal atresia and small intestinal atresia (table 3). The aORs ranged from 1.58 for anophthalmia/microphthalmia to 2.65 for oesophageal atresia. Of these, six defects had CI that excluded the null, although some of the CI were wide. Many of the defects with elevated aORs in the main analysis moved further from the null when we explored specific occupational subgroups. Among those who worked as a maid, all nine elevated aORs observed in the main analysis remained elevated, and six defects had CI that excluded the null. Among those who worked as a janitor, we observed three elevated aORs (CLP, anorectal atresia, oesophageal atresia), of which two estimates excluded the null. We observed two defects (anotia/microtia and small intestinal atresia) with elevated aORs in those with secondary code as a cleaner, and both had CI that excluded the null (online supplemental table S2). Furthermore, the aORs among those who performed cleaning tasks but were not classified as a cleaner were largely null, with the exception of encephalocele (online supplemental table S2).

In the sensitivity analysis focusing on isolated birth defects, we calculated aORs for 14 of the 19 birth defects (online supplemental table S3). Among the nine defects with elevated aOR in the main analysis, we were unable to calculate estimates for two defects (Dandy Walker malformation and holoprosencephaly). Estimates among specific occupational subgroups and isolated defects were largely similar to the main analysis results for each occupational subgroup. In the second sensitivity analysis restricted to those who reported working 40 or more hours per week, we calculated estimates for 11 of 19 birth defects (online supplemental table S4). We observed nine elevated aORs above 1.5 and four excluded the null, including glaucoma, anotia/microtia, CLP and anorectal atresia. Our analysis of other cleaning occupation subgroups showed comparable aOR to the main analysis among those who worked 40 or more hours.

DISCUSSION

Our study estimated the association between maternal occupation in cleaning-related jobs during early pregnancy and 19 specific birth defects, finding aORs for 9 out of 19 birth defects were elevated (aOR >1.50), including defects in five organ systems. We observed elevated aORs for nine birth defects among mothers who worked as a maid, while we observed elevated aORs for three defects among those employed as a janitor. The defects with elevated risks in the main analysis remained elevated when restricted to isolated birth defects and when restricted to those who reported working 40 hours or more per week.

Our results showed a significant association between maternal occupation as a cleaner and orofacial clefts (aOR=1.47), especially CLP (aOR=1.64). The aORs for CLP were elevated among cleaners, maids and janitors, although the CI for janitors included 1.0. The aORs moved slightly further from the null after restricting to isolated cases and when we restricted to those who worked more than 40 hours per week. Our findings for oral clefts using the final NBDPS data were consistent with previous NBDPS studies, exploring risk among those in cleaning occupations using pregnancies from 1997 to 2003 and 1997 to 2004,[11 12] yet an NBDPS study exploring occupational pesticide use found null results for CLP.[18] Additionally, a multicentre European study observed maternal occupation in housekeeping service was positively associated with orofacial clefts (OR=2.80), and a Texas case–control study found a significant positive association between maternal cleaning-related occupations and CLP.[19 20] Yet, other studies have found null results between those in cleaning occupations and orofacial clefts, with a study in Singapore reporting no association.[21] This study used older data from 1994 to 1998, and many potential confounding variables were not available, which might explain differences between these results and our present findings.

Furthermore, we observed that working as a cleaner was associated with NTDs, particularly anencephaly. The elevated OR for any NTDs (aOR=1.52) was driven by the association

Table 1 Demographic characteristics of controls who worked as cleaners during early pregnancy by occupational cleaning category, National Birth Defects Prevention Study, 1997–2011

	Women assigned a primary Standard Occupational Classification System cleaner code				Women assigned a primary Standard Occupational Classification System code other than cleaner, but performed cleaning tasks		
	All cleaners* n=241	Maids n=191	Janitors n=41	Other cleaners† n=9	Secondary code as cleaners‡ n=60	Cleaning tasks§ n=371	Non-cleaners n=7126
Characteristics	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Maternal age, in years	26.0 (6.0)	25.7 (6.1)	26.5 (5.1)	29.4 (5.9)	27.5 (6.6)	24.5 (5.4)	28.6 (2.7)
Maternal age categories	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
< 20 years old	26 (10.8)	24 (12.6)	1 (2.4)	1 (11.1)	7 (11.7)	67 (18.1)	389 (5.5)
20–34 years old	193 (80.1)	147 (77.0)	39 (95.1)	7 (77.8)	40 (66.7)	283 (76.3)	5619 (78.9)
35+ years old	22 (9.1)	20 (10.5)	1 (2.4)	1 (11.1)	13 (21.7)	21 (5.7)	1118 (15.6)
Maternal race/ethnicity							
Non-Hispanic White	95 (39.4)	78 (40.8)	16 (39.0)	1 (11.1)	26 (43.3)	194 (52.3)	4683 (65.7)
Non-Hispanic Black	36 (14.9)	31 (16.2)	3 (7.3)	2 (22.2)	5 (8.3)	49 (13.2)	805 (11.3)
Hispanic	97 (40.3)	73 (38.2)	20 (48.8)	4 (44.4)	26 (43.3)	102 (27.5)	1198 (16.8)
Other race	13 (5.4)	9 (4.7)	2 (4.9)	2 (22.2)	3 (5.0)	26 (7.0)	440 (6.2)
Pre-pregnancy body mass index							
Underweight	11 (4.6)	7 (3.7)	4 (9.8)	0 (0)	2 (3.3)	18 (4.9)	321 (4.5)
Normal weight	116 (48.1)	92 (48.2)	21 (51.2)	3 (33.3)	24 (40.0)	175 (47.2)	3798 (53.3)
Overweight	49 (20.3)	42 (22.0)	4 (9.7)	3 (33.3)	11 (18.3)	77 (20.8)	1633 (22.9)
Obese	45 (18.7)	35 (18.3)	8 (19.5)	2 (22.2)	11 (18.3)	86 (23.2)	1258 (17.7)
Number of previous pregnancies							
No prior pregnancy	72 (29.9)	55 (28.8)	13 (31.7)	4 (44.4)	15 (25.0)	148 (39.9)	2321 (32.6)
One or more prior pregnancies	169 (70.1)	136 (71.2)	28 (68.3)	5 (55.6)	45 (75.0)	222 (59.8)	4084 (67.4)
Early pregnancy cigarette smoking	62 (25.7)	55 (28.8)	7 (17.1)	0 (0)	16 (26.7)	116 (31.3)	1249 (17.5)
No	179 (74.3)	136 (71.2)	34 (82.9)	9 (100.0)	44 (73.3)	255 (68.7)	5875 (82.4)
Early pregnancy alcohol use	71 (29.5)	58 (30.4)	10 (24.4)	3 (33.3)	19 (31.7)	131 (35.3)	3097 (43.5)
No	169 (70.1)	133 (69.6)	31 (75.6)	5 (55.6)	41 (68.3)	239 (64.4)	4005 (56.2)
Educational attainment							
Less than high school	73 (30.3)	58 (30.4)	13 (31.7)	2 (22.2)	25 (41.7)	76 (20.5)	561 (7.9)
High school	98 (40.7)	82 (42.9)	14 (34.2)	2 (22.2)	17 (28.3)	147 (39.6)	1500 (21.1)
Some colleges or more	69 (28.6)	50 (26.2)	14 (34.2)	5 (55.6)	18 (30.0)	148 (39.0)	5052 (70.9)
Pre-existing diabetes	1 (0.4)	1 (0.5)	0 (0)	0 (0)	0 (0)	2 (0.5)	45 (0.6)
No	239 (99.2)	189 (99.0)	41 (100.0)	9 (100.0)	60 (100.0)	369 (99.5)	7074 (99.3)
Folic-acid supplementation use at conception¶	163 (67.6)	132 (69.1)	26 (63.4)	5 (55.6)	37 (61.7)	214 (57.7)	2974 (41.7)
No	78 (32.4)	59 (30.9)	15 (36.6)	4 (44.4)	23 (38.3)	157 (42.3)	4151 (58.3)
Maternal place of birth							
Foreign country	95 (39.4)	73 (38.2)	17 (41.5)	5 (55.6)	27 (45.0)	64 (17.3)	1052 (14.8)
USA	146 (60.6)	118 (61.8)	24 (58.5)	4 (44.4)	33 (55.0)	307 (82.7)	6066 (85.1)
Years in the USA**	95	73	17	5	27	64	1052
0–5 years	40 (42.1)	28 (5.5)	10 (58.8)	2 (40.0)	8 (29.6)	23 (35.9)	218 (20.7)
6–10 years	24 (25.3)	19 (26.0)	3 (17.7)	2 (40.0)	11 (40.7)	15 (23.4)	265 (25.2)
11–20 years	25 (26.3)	22 (30.1)	2 (11.8)	1 (20.0)	3 (11.1)	17 (26.6)	256 (24.3)
21 years or more	0 (0)	0 (0)	2 (11.76)	0 (0)	3 (11.1)	4 (6.3)	170 (16.2)
Study site							
Arkansas	34 (14.1)	32 (16.8)	1 (2.4)	1 (11.1)	14 (23.3)	38 (10.2)	911 (12.8)
California	25 (10.4)	20 (10.5)	5 (12.2)	0 (0)	5 (8.3)	34 (9.2)	625 (8.8)
Georgia	33 (13.7)	24 (12.6)	6 (14.6)	3 (33.3)	7 (11.7)	36 (9.7)	797 (11.2)
Iowa	24 (10.0)	18 (9.4)	6 (14.6)	0 (0)	5 (8.3)	64 (17.3)	937 (13.2)
Massachusetts	15 (6.2)	13 (6.8)	1 (2.4)	1 (11.1)	3 (5.0)	14 (3.8)	1025 (14.4)
New Jersey	10 (4.2)	5 (2.6)	3 (7.3)	2 (22.2)	2 (3.3)	3 (0.8)	373 (5.2)
New York	17 (7.1)	16 (8.4)	1 (2.4)	0 (0)	7 (11.7)	38 (10.2)	626 (8.8)
North Carolina	23 (9.5)	18 (9.4)	4 (9.8)	1 (11.1)	2 (3.3)	35 (9.4)	613 (8.6)
Texas	28 (11.6)	24 (12.6)	4 (9.8)	0 (0)	11 (18.3)	58 (15.6)	604 (8.5)

continued

Table 1 continued

Characteristics	Women assigned a primary Standard Occupational Classification System cleaner code				Women assigned a primary Standard Occupational Classification System code other than cleaner, but performed cleaning tasks		Non-cleaners n=7126
	All cleaners* n=241	Maids n=191	Janitors n=41	Other cleaners† n=9	Secondary code as cleaners‡ n=60	Cleaning tasks§ n=371	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Utah	32 (13.3)	21 (11.0)	10 (24.4)	1 (11.1)	4 (6.7)	51 (13.8)	615 (8.6)

*Includes maids, janitors, car cleaners, building cleaners and first-line supervisor/managers of housekeeping and janitorial workers. Four women held more than one job in these occupations during the critical period, thus, the subcategories do not sum to the total.
†Includes car cleaners, building cleaners, first-line supervisor/managers of housekeeping and janitorial workers combined.
‡Secondary Standard Occupation Classification code as a cleaner in addition to a primary Standard Occupation Classification code as another occupation.
§Primary and Secondary Standard Occupation Classification code as a non-cleaner occupation, but performed cleaning tasks as part of their job.
¶Folic acid supplementation use from one month before conception through the first month of pregnancy.
** Years in the USA for mothers born in a foreign country.

with anencephaly (aOR=1.98). We observed elevated aORs for anencephaly among all cleaners, maids and those in non-cleaning occupations who conducted cleaning tasks, with the aORs being highest for maids. Our findings align with previous NBDPS research[11 12] and with a study in Texas.[22] Nevertheless, our results conflict with a Finnish case–control study that did not find an association between cleaning occupations and NTDs.[23] However, there were key differences, including the use of older data (1976–1978) and a smaller sample.

We also found elevated aORs between individuals working as a cleaner and defects in the gastrointestinal system, observing those working as a janitor to have more than three times the risk for anorectal atresia and nearly four times higher risks for oesophageal atresia in offspring compared with those who worked as a non-cleaner. We also observed an association between mothers who reported working in a cleaning-related occupation and anotia/microtia. While these results support the findings in other NBDPS research, these associations have not been observed in other datasets to date.[11 12]

Our analysis focused on job titles and tasks, so we were unable to examine specific hazards, such as specific chemical exposures, which may explain our observations. Harmful substances, including VOCs and EDCs, are frequently present in industrial-strength and specialised cleaning products. These substances might interfere with cellular processes and hormonal functions during critical periods of fetal development, leading to birth defects.[24–26] In particular, VOCs are known to interfere with cellular processes and disrupt neural and ocular development, potentially contributing to the development of neural tube and eye defects, and have been observed in other research studies.[27–30] In fact, two studies observed that exposure to organic solvents during early pregnancy contributed to vision deficiencies or

Table 2 Work characteristics of women who worked as cleaners during early pregnancy by occupational cleaning category, National Birth Defects Prevention Study, 1997–2011

Characteristics	Women assigned a primary Standard Occupational Classification System cleaner code				Women assigned a primary Standard Occupational Classification System code other than cleaner, but performed cleaning tasks		Non-cleaners n=26235
	All cleaners* n=1109	Maids n=868	Janitors n=179	Other cleaners† n=66	Secondary code as cleaners‡ n=241	Cleaning tasks§ n=1351	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Number of jobs held							
One job	875 (78.9)	684 (78.8)	137 (76.5)	54 (81.8)	193 (80.1)	1086 (80.4)	23 671 (90.2)
Two or more jobs	234 (21.1)	184 (21.2)	42 (23.5)	12 (18.2)	48 (19.9)	265 (19.6)	2564 (9.8)
Hours worked per week							
40 or more hours	402 (36.3)	302 (34.8)	63 (35.2)	39 (59.1)	71 (29.5)	542 (40.1)	14832 (56.5)
Less than 40 hours	695 (62.7)	555 (63.9)	115 (64.3)	27 (40.9)	166 (68.7)	795 (58.9)	11304 (43.1)
Tasks performed	12 (1.1)	11 (1.3)	1 (0.6)	0 (0)	4 (1.7)	14 (1.0)	99 (0.4)
Cleaning bathrooms	256 (23.1)	199 (22.9)	49 (27.4)	9 (13.6)	57 (23.7)	107 (7.9)	–
Housekeeping	49 (4.4)	38 (4.4)	6 (3.4)	6 (9.1)	3 (1.2)	58 (4.3)	–
Sweeping and mopping floors	266 (24.0)	193 (22.2)	68 (38.0)	7 (10.6)	72 (29.9)	249 (18.4)	–
Scrubbing	17 (1.5)	13 (1.5)	2 (1.1)	2 (3.0)	4 (1.7)	9 (0.7)	–
Vacuuming floors	180 (16.2)	143 (16.5)	28 (15.6)	10 (15.2)	33 (13.7)	37 (2.7)	–
Other cleaning tasks	7 (0.6)	3 (0.4)	4 (2.2)	0 (0)	2 (0.8)	9 (0.7)	–

*Includes maids, janitors, car cleaners, building cleaners and first-line supervisor/managers of housekeeping and janitorial workers. Four women held more than one job in these occupations during the critical period, thus the subcategories do not sum to the total.
†Includes car cleaners, building cleaners, first-line supervisor/managers of housekeeping and janitorial workers combined.
‡Secondary Standard Occupation Classification code as a cleaner in addition to a primary Standard Occupation Classification code as another occupation.
§Primary and Secondary Standard Occupation Classification code as a non-cleaner occupation, but performed cleaning tasks as part of their job.

Table 3 Adjusted ORs and 95% CIs for the association between cleaning occupation category and selected birth defects, National Birth Defects Prevention Study, 1997–2011*

	Non-cleaners (n=19 109)	All cleaners‡ (n=868)		Maids (n=677)		Janitors (n=138)	
Birth defects†	**N**	**N**	**OR (95% CI)**	**N**	**OR (95% CI)**	**N**	**OR (95% CI)**
Neural tube defects	1187	76	1.52 (1.13 to 2.05)	65	1.66 (1.20 to 2.29)	9	0.92 (0.40 to 2.09)
Spina bifida	712	42	1.41 (0.97 to 2.05)	33	1.42 (0.93 to 2.15)	7	1.14 (0.44 to 2.93)
Anencephaly	352	27	1.98 (1.26 to 3.13)	25	2.37 (1.47 to 3.81)	2	–
Encephalocele	123	7	0.90 (0.32 to 2.51)	7	1.12 (0.40 to 3.13)	0	–
Cerebellar hypoplasia	44	1	–	0	–	1	–
DWM	107	9	2.04 (0.95 to 4.39)	7	1.89 (0.79 to 4.51)	0	–
Holoprosencephaly	84	8	1.79 (0.80 to 4.04)	6	1.99 (0.83 to 4.74)	1	–
Hydrocephaly	293	13	0.85 (0.43 to 1.70)	8	0.60 (0.24 to 1.48)	4	–
Ano/microphthalmia	133	9	1.58 (0.78 to 3.24)	7	1.56 (0.70 to 3.47)	2	–
Cataracts	224	7	0.77 (0.33 to 1.79)	5	0.71 (0.26 to 1.97)	2	–
Glaucoma	114	10	2.58 (1.24 to 5.36)	8	2.65 (1.17 to 6.01)	1	–
Anotia/microtia	333	37	2.34 (1.55 to 3.52)	33	2.74 (1.78 to 4.23)	3	–
Oral clefts	2782	152	1.47 (1.17 to 1.85)	118	1.45 (1.12 to 1.88)	22	1.19 (0.68 to 2.09)
Cleft palate only	965	45	1.33 (0.93 to 1.89)	33	1.22 (0.81 to 1.84)	6	0.99 (0.39 to 2.54)
Cleft lip only	671	29	1.36 (0.89 to 2.07)	23	1.41 (0.89 to 2.24)	4	–
Cleft lip and palate	1146	78	1.64 (1.23 to 2.20)	62	1.64 (1.19 to 2.27)	12	1.51 (0.76 to 3.00)
Anorectal A/S	628	32	1.32 (0.86 to 2.00)	19	0.98 (0.58 to 1.67)	13	3.31 (1.65 to 6.65)
Duodenal A/S	145	4	–	4	–	0	–
Oesophageal A/S	490	34	2.65 (1.76 to 3.98)	24	2.52 (1.59 to 4.01)	10	3.75 (1.70 to 8.23)
Small intestinal A/S	273	20	2.10 (1.28 to 3.44)	20	2.71 (1.64 to 4.47)	0	–
ABS	199	7	0.91 (0.41 to 1.99)	6	0.93 (0.40 to 2.17)	1	–

*Analyses were adjusted for maternal age at delivery, maternal race, maternal highest educational attainment, maternal pre-pregnancy body mass index, maternal folic acid intake, maternal smoking history, parity and study centre. The reference group included working women who had non-cleaning jobs during pregnancy.
†Most analyses included 7126 unexposed controls, 241 'all cleaners' exposed controls, 191 maids exposed controls, 41 janitor exposed controls, 60 secondary code as cleaners exposed controls and 371 tasks as cleaners exposed controls. The cataracts and glaucoma analyses included 5974 unexposed controls, 205 'all cleaners' exposed controls, 159 maids exposed controls, 37 janitor exposed controls, 41 secondary code as cleaners exposed controls and 335 tasks as cleaners exposed controls. The oral cleft analyses included 7049 unexposed controls, 234 'all cleaners' exposed controls, 184 maids exposed controls, 41 janitor exposed controls, 60 secondary code as cleaners exposed controls and 366 tasks as cleaners exposed controls.
‡Includes maids, janitors, car cleaners, building cleaners and first-line supervisor/managers of housekeeping and janitorial workers. Four women held more than one job in these occupations during the critical period, thus, the subcategories do not sum to the total. Additionally, 'Other cleaners' (car cleaners, building cleaners, first-line supervisor/managers of housekeeping and janitorial workers) were included in the 'All cleaners' analysis but were not explored as a separate group given the small numbers.
ABS, Amniotic Band Syndrome; A/S, atresia/stenosis; DWM, Dandy-Walker malformation.

abnormalities in offspring.[30 31] We observed elevated risks of both central nervous and eye systems among cleaners and maids in particular, who may work under limited ventilation settings, such as hotels/motels and restaurants. In addition to VOCs, EDCs exist in industrial-strength products such as pesticides, insecticides and fungicides that could affect hormonal functions and impact fetal development.[32 33] Studies have found pesticides are positively associated with orofacial clefts, holoprosencephaly and gastrointestinal obstruction, which suggest a mechanism for the elevated risks for these defects that we observed, especially our findings of increased risks among janitors who usually handle a broader range of outdoor cleaning tasks using heavy-duty cleaning products.[34 35]

The physical hazards of cleaning occupations could play a role in the observed increased risks of certain birth defects. Yet, NBDPS lacked detailed information on the physical demands of cleaning occupations, and our analysis focused on job titles. Even though moderate physical activity is beneficial for pregnant women and their offspring,[36] intensive physical activity, like that undertaken by cleaners who vigorously clean throughout their workday, could be associated with negative impacts on the development of the fetus. According to the Bureau of Labor Statistics, on average, those who work as cleaners spend nearly 96% of the workday standing.[37] Prolonged standing during pregnancy can lead to decreased blood flow and increased blood pressure, potentially causing placental insufficiency.[38] Although limited evidence has linked placental insufficiency and birth defects, compromised placental function can lead to maternal-fetal hypoxia and nutrient deprivation (reduced placental perfusion), contributing to underdevelopment of the fetus.

While our study provides valuable insights into associations between maternal occupation in cleaning-related jobs and specific birth defects, the strengths and limitations should be considered. First, the analysis used the final study data from NBDPS data from ten birth defect registries across a 15-year period, with case classification and review conducted by clinical geneticists. Such a detailed review and classification ensures consistency in determining case eligibility and birth defect classification.[39] Though occupational epidemiologists and industrial hygienists utilised rigorous classification procedures, there is a possibility that reported job titles and duties were inaccurate if mothers misunderstood the questions or recalled their job details incorrectly. NBDPS data were collected between 6 weeks and 2 years after the estimated delivery date; there is a chance for mothers to misremember job information. Yet, we expect this to be infrequent, given that NBDPS asked about job titles, duties and descriptions, which are things that do not change frequently and may be easier to remember than other prenatal exposures.

In addition, we would expect that any misclassification of occupation would be non-differential by case/control status, resulting in bias that would be towards the null. Thus, the associations we observed would be underestimating the true association.

We adjusted our estimates for a wide range of potential confounders identified a priori. However, residual confounding due to incomplete control of covariates or confounding by unmeasured factors such as dietary habits, preconceptional education and care, environmental exposures outside of workplace settings, other lifestyle factors or genetic predispositions cannot be dismissed. Cleaning workers may differ substantially from non-cleaning workers in socioeconomic status and health status. Our analysis compared those in cleaning occupations to those in other occupations, and such analysis avoids bias due to the healthy worker effect. Selection bias due to non-participation could also bias our results if non-participation was associated with both case/control status and maternal occupation as a cleaner. Although the NBDPS had relatively high participation rates: 67% for cases and 64% for control mothers, non-participation rates may still influence the results if those who work as cleaners are less likely to participate and mothers of those with birth defects are less likely to participate due to stress or other factors.

Another limitation of our study is the small sample size for certain defects, which resulted in wide CIs. While our findings are suggestive of an increased risk, they should be interpreted with caution. We chose to explore specific birth defects, despite the small numbers, as understanding associations with specific birth defects is particularly helpful because teratogens tend to impact specific developmental pathways.[40] Our sensitivity analyses were particularly impacted by smaller numbers, but exploring isolated birth defects and those with extended working hours provides a deeper understanding of the associations and their robustness. Finally, we calculated adjusted estimates for 17 of the 19 studied birth defects in our main analysis. Based on a significance level of 0.05, we would expect one significant finding by random chance alone; we observed six significant associations. This suggests that random chance may be unlikely to explain all of our findings, and further investigation is suggested to confirm these results, as well as to identify likely causal factors driving the association, so that those specific factors could be appropriately mitigated.

In conclusion, our study has highlighted elevated risks of specific birth defects associated with maternal occupation in cleaning jobs. Yet, further research is crucial to confirm and explore the underlying mechanisms. Moreover, subsequent studies that clarify the risks associated with specific cleaning subgroups, tasks and the cleaning products used by different workers would enhance a better understanding of which activities and substances are most harmful, thereby informing more targeted prevention messages for women working in cleaning occupations during early pregnancy.

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