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ScienceDirect
Int. J. Hyg. Environ. Health 211 (2008) 50–58
International Journal of Hygiene and Environmental Health
www.elsevier.de/ijheh

Residential proximity to waste sites and industrial facilities and chromosomal anomalies in offspring

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Received 29 September 2006; received in revised form 26 November 2006; accepted 28 February 2007

Abstract

A few studies have found chromosomal anomalies in offspring associated with a maternal residence near waste sites, but did not examine the effect of living near industrial facilities, and most combined specific anomalies into heterogeneous groups. With a case–control study design, we investigated whether maternal residential proximity to hazardous waste sites or industrial facilities with chemical air emissions was associated with chromosomal anomalies in births. Maternal residences of 2099 Texas births with chromosomal anomalies and 4368 control births without documented malformations were related to boundaries of hazardous waste sites and street addresses of industrial facilities through geographic information systems. With adjustment for maternal age, race/ethnicity, and education, maternal residence within 1 mile of a hazardous waste site (relative to farther away) was not associated with chromosomal anomalies in offspring except for Klinefelter variants among Hispanic births (odds ratios (OR) 7.9, 95% confidence interval (CI) 1.1–42.4). Women 35 years or older who lived within 1 mile of industries with emissions of heavy metals were two times more likely (95% CI 1.1–4.1) than women living farther away to have offspring with chromosomal anomalies including trisomies 13, 18, or 21 or sex chromosome abnormalities. Among women 40 years or older, maternal residence within a mile of industries with solvent emissions was associated with chromosomal anomalies in births (OR 4.8, 95% CI 1.2–42.8). Study findings suggest some relation between residential proximity to industries with emissions of solvents or heavy metals and chromosomal anomalies in births to older mothers.

Keywords: Chromosomal anomalies; Hazardous waste sites; Industrial pollution; Residential exposure; Geographic information system

Background

Contaminants at waste sites and in solid waste leachates are known to induce chromosomal aberrations and DNA damage in several animal models including

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1438-4639/$ - see front matter
doi:10.1016/j.ijheh.2007.02.009

wild rats (Eckl and Riegler, 1997) and mice (Chandra et al., 2006; Tewari et al., 2006). Results from epidemiologic studies have also suggested increased risks of chromosomal anomalies in offspring of women who lived near hazardous waste sites (Geschwind et al., 1992; Dodds and Seviour, 2001; Orr et al., 2002; Vrijheid et al., 2002), although Cordier et al. (2004) found no association between such anomalies and maternal residence in communities with municipal waste incinerators.

Most of these studies have grouped chromosomal anomalies into a limited single category such as trisomy 21 or into categories so broad that they conflate heterogeneous conditions. Furthermore, previous studies have focused on residential proximity to waste sites and not on the potential risk associated with living near more general sources of industrial emissions. Yet, results of several studies indicated a relation between exposure to industrial pollution and chromosomal aberrations in both experimental animal models (Somers et al., 2002) and human populations (Major et al., 1998; Michalska et al., 1999).

In this study, we examined the relation between maternal residential proximity to hazardous waste sites and industrial air emissions, and chromosomal anomalies in offspring. We categorized chromosomal anomalies by type and also studied the effects of several classes of contaminants including solvents, heavy metals, and polycyclic aromatic hydrocarbons (PAHs).

Methods

Data for this study came from a project examining the relation between residential proximity to environmental hazards and selected congenital malformations in offspring (Brender et al., 2006a). Case and control births were selected from 1996 to 2000 births to Texas (USA) state residents. The Texas Birth Defects Registry (TBDR) conducts active birth defect surveillance by reviewing medical facility log books, hospital discharge lists, and other records. For the years 1996–1998, only selected public health regions in Texas were included in this birth defects surveillance system; since 1999, the TBDR has covered affected births occurring to all mothers residing in Texas. Although the TBDR includes spontaneous abortions and elective terminations with eligible defects in the surveillance system, we restricted this study to live births and fetal deaths (unless the termination had a vital record) because of the availability of vital records with information about maternal addresses as well as demographic characteristics.

In the TBDR, abstracts of cases with chromosomal anomalies undergo additional review by a clinical geneticist to assure appropriate classification.

Cases were included in this study if they had one or more of the British Pediatric Association (BPA) Classification of Diseases codes 758.000–758.990. Through vital record numbers supplied by the TBDR, registry cases were linked to their respective computerized live birth or fetal death records. Overall, we captured 81% of births during 1996–2000 that were identified by the registry as having chromosomal anomalies. A total of 206 live births, 66 spontaneous fetal deaths, and 258 induced terminations were excluded; these cases either did not have a live birth or fetal death certificate (induced terminations or spontaneous fetal deaths less than 20 weeks gestation) or linkage to their respective vital records was unsuccessful (live births or fetal deaths 20-weeks gestation or greater).

Chromosomal anomalies were categorized into specific diagnostic groups including trisomy 21 (BPA codes 758.000–758.090), trisomy 13 (BPA codes 758.100–758.190), trisomy 18 (BPA codes 758.200–758.295), autosomal deletion syndromes (BPA codes 758.300–758.390), balanced autosomal translocation in normal individuals (BPA code 758.400), other conditions due to autosomal anomalies (BPA codes 758.500–758.590), monosomy X variants (BPA codes 758.600–758.690), Klinefelter variants (BPA codes 758.700–758.790), and other sex chromosome anomalies (BPA codes 758.800–758.890).

A total of 4965 control births without documented congenital malformations were randomly selected for the entire project from the computerized live birth certificate files for births occurring during 1996–2000. These control records were frequency-matched to the entire sample of congenital malformations by year of birth and public health region of maternal residence. The Institutional Review Boards of the Texas Department of State Health Services, Texas State University, and Texas A&M University approved the research protocol.

Sources and methods related to environmental data are described in detail by Brender et al. (2006a). Briefly, we obtained information about National Priority List (NPL) hazardous waste sites in Texas including site characteristics and contaminants from the Agency for Toxic Substances and Disease Registry (2005) online Hazardous Substance Release/Health Effects Database (HazDat). Study staff abstracted information about state superfund sites from paper and microfilmed files stored at the Texas Commission on Environmental Quality in Austin, Texas. A total of 43 NPL sites and 70 state superfund sites were active (undergoing assessment and remediation) at the beginning of the study period.

We obtained information about industrial facilities, their locations, chemical air releases by year, and type of industry from the online Toxic Release Inventory (TRI) databases (United States Environmental Protection

Agency, 2006). Industries were further grouped by type including petroleum refineries, primary metals or smelter facilities, or chemical industries. Hazardous waste site contaminants and industrial air emissions were also categorized into whether heavy metals, PAHs, or solvents were present.

Street addresses at delivery of case and control mothers were geocoded with ArcGIS 8.3 Centrus Geocoder for Arc GIS plug-in and its accompanying reference street database. Geocodes were assigned to maternal addresses without knowledge of case or control status. We digitized hazardous waste site boundaries from Digital Orthophoto Quarter Quads (DOQQ) images with 1-m resolution. Although the TRI databases contained company-reported geographic coordinates, we found errors with some coordinates and noted others to be imprecise because of rounding of decimal degrees. Therefore, industry addresses were geocoded by the study team to reduce misclassification. A total of 1648 facilities with reported air emissions of chemicals were identified during 1996–2000, ranging from 1217 to 1437 per year.

Maternal addresses were related to hazardous waste site boundaries and street addresses of industrial facilities through a geographic information system within the ArcGIS environment and through a query tool that we developed (GIS EpiLink) (Zhan et al., 2006). Actual distances within 10 miles of these sites and facilities were assigned to the chromosomal anomaly case and control records. For most analyses, a distance of less than 1 mile was used to define residential "proximity" to waste sites or industrial facilities. The referent group consisted of women who lived 1 or more miles from these sites and facilities.

We used unconditional logistic regression and exact logistic regression (in analyses with sparse data) to obtain odds ratios (OR) and 95% confidence intervals (CI) for risk of chromosomal anomalies (any and specific types) associated with living within a mile of a hazardous waste site (any site, NPL or state superfund site, types of contaminants present (heavy metals, PAHs, solvents)) or industrial facility with reported air emissions (any facility, types of air releases (heavy metals, PAHs, solvents), and types of facilities (petroleum refineries, primary metals or smelter facilities, or chemical industries)). We considered the following factors as covariates: year of birth (1996–2000), infant sex, public health region of maternal residence (11 regions in Texas), and maternal age (<20, 20–24, 25–29, 30–34, 35–39, 40+ years), education (<9, 9–11, 12, 13–15, 16 or more years), and race/ethnicity (non-Hispanic white, Hispanic, African-American, and other). Because adjustment for maternal age, education, and race/ethnicity changed risk estimates by more than 10% in several analyses, all risk estimates were adjusted for these covariates. Adjustment for public health region of maternal residence had minimal or no effect on risk estimates with the exception of the OR for balanced autosomal translocations and other autosomal anomalies and proximity to industrial facilities. Adjustment for year of birth did not change any of the risk estimates by more than 10% and therefore was not included in any of the final models.

We also examined the relation between maternal residences near hazardous waste sites or industrial facilities and chromosomal anomalies by age because increased maternal age was strongly related to risk for some types of chromosomal anomalies in offspring in this study. Furthermore, several recent studies found a relation between environmental exposures in older women and adverse reproductive outcomes in offspring including heart defects (Yauck et al., 2004), oral clefts (Brender et al., 2006b), and intrauterine growth retardation (Sonnenfeld et al., 2001).

To assess the potential effect of excluding pregnancy terminations, we stratified the analyses of proximity to industrial facilities and chromosomal defects by timing of prenatal care as a marker for prenatal diagnosis (prenatal care within the first 4 months, prenatal care after the 4th month or no prenatal care). Numbers of exposed cases and controls were insufficient to conduct this subgroup analysis with residential proximity to hazardous waste sites.

Results

For the period of 1996–2000, a total of 2334 chromosomal anomalies were identified among live births and fetal deaths to Texas residents. Similar proportions of case and control maternal addresses were successfully assigned geocodes including 2099 (90%) case mothers' addresses and 4368 (88%) control mothers' addresses.

Table 1 shows the numbers available for study, maternal characteristics, and proportions of addresses assigned geocodes for each anomaly group and the control births. Case mothers tended to be older than control mothers, with the exception of mothers giving birth to offspring with autosomal deletion syndromes or monosomy X variants.

A total of 54 case mothers (2.6%) and 117 control mothers (2.7%) lived within a mile of a hazardous waste site at the time of delivery (Table 2). With adjustment for maternal age, education, and race/ethnicity, odds ratios were consistent for unity for specific chromosomal anomalies and residential proximity to these sites. However, Hispanic women who lived near hazardous wastes sites were approximately eight times more likely (OR 7.9, 95% CI 1.1–42.4) to have offspring with Klinefelter variants than Hispanic women who lived

Table 1. Characteristics of study population[a]

	Comparison births (n = 4368)	Trisomy 21 (n = 1208)	Trisomy 13 (n = 114)	Trisomy 18 (n = 201)	Autosomal deletions syndromes (n = 159)	Balanced autosomal translocation (n = 33)	Other autosomal anomalies (n = 201)	Monosomy X variants (n = 117)	Klinefelter variants (n = 31)	Other sex chromosome anomalies (n = 57)
Maternal age[b] *(years)* (%)										
<20	16.5	9.5	15.8	8.0	20.8	3.0	14.4	16.2	9.7	3.5
20–24	27.9	14.9	22.8	15.5	25.2	15.2	27.9	33.3	9.6	21.1
25–29	26.4	17.3	18.4	17.0	23.9	21.2	23.9	18.8	3.2	12.3
30–34	18.9	20.1	15.8	18.0	21.4	21.2	14.4	15.4	9.7	15.8
35–39	8.7	23.2	18.4	26.0	8.2	33.3	14.4	14.5	38.7	36.8
> 39	1.7	14.9	8.8	15.5	0.6	6.1	5.0	1.7	29.0	10.5
Maternal race/ethnicity[c](%)										
Non-Hispanic white	39.4	36.0	32.5	40.3	37.1	45.5	35.8	38.5	25.8	35.1
Hispanic	46.7	53.8	49.1	43.3	47.8	42.4	48.3	53.8	51.6	47.4
African-American	10.8	7.1	14.0	11.4	11.9	3.0	12.4	4.3	16.1	14.0
Other	3.2	3.1	4.4	5.0	3.1	9.1	3.5	3.4	6.5	3.
Maternal education[d] (years) (%)										
<9	10.8	15.8	12.1	7.5	11.6	9.1	12.1	8.6	9.7	5.3
9–11	22.8	18.6	20.6	18.3	27.7	9.1	20.5	23.3	16.1	15.8
12	30.6	25.8	31.8	27.4	34.8	33.3	33.7	37.9	25.8	40.4
13–15	17.3	18.3	11.2	19.4	10.3	18.2	16.3	13.8	16.1	22.8
16 or more	18.5	21.5	24.3	27.4	15.5	30.3	17.4	16.4	32.3	15.8
Address geocoded (%)	88.0	90.1	92.7	88.9	87.8	94.3	87.4	91.4	91.2	96.6

[a]Includes only case and control births for which maternal addresses were georeferenced. Monosomy X variants include female births and Klinefelter variants include male births.
[b]Information missing for one Down syndrome case birth and one trisomy 18 case birth.
[c]Information missing for two comparison births.
[d]Information missing for 66 comparison births and 32 Down syndrome, 7 trisomy 13, 15 trisomy 18, 4 autosomal deletion syndrome, 1 monosomy X variant, and 11 other autosomal anomaly case births.

farther away. This association was based on three exposed Hispanic case and 13 control mothers. Examination of nine specific chromosomal anomaly groups and all chromosomal anomalies combined revealed no compelling associations between these anomalies and type of site (NPL or state superfund site), types of contaminants present at these sites (heavy metals, PAHs, or solvents), nor effect modification by maternal age. Numbers of exposed cases and controls were few, however, leading to imprecise estimates.

A higher proportion of the study population lived within a mile of one or more industrial facilities than hazardous waste sites including 312 (14.9%) case mothers and 608 (13.9%) control mothers (Table 3). Although the OR for all chromosomal anomalies combined in relation to maternal residential proximity to these facilities was consistent with unity (adjusted OR 1.1, 95% CI 0.92–1.3), living near such facilities showed some association with Klinefelter variants (adjusted OR 2.9, 95% CI 1.1–7.3) and autosomal deletion syndromes (adjusted OR 1.5, 95% CI 1.0–2.3). Overall, the proportions of case and control mothers living near specific types of facilities and air releases were similar, and the 95% CI of the OR for these defects were consistent with unity.

Maternal age modified the association between maternal residence near industrial facilities and risk for chromosomal anomalies in offspring (Table 4). Among women 40 years or older, those who lived within a mile of these facilities (relative to women 40 years or older who lived further away) were more likely to have offspring with chromosomal anomalies including trisomy 21, trisomy 18, and other autosomal anomalies. With adjustment for maternal race/ethnicity and education, women who were 40 years or older and who lived within a mile of facilities with solvent emissions were 4.8 times more likely (95% CI 1.2–42.8) to have births with chromosomal anomalies than mothers who lived a mile

Table 2. Maternal residential proximity to hazardous waste sites and selected chromosomal anomalies in offspring

Group	Number (%) within 1 mile of waste site	Number (%) ⩾1 mile from site (referent)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio[a] (95% CI)
Controls	117 (2.7)	4251 (97.3)	—	—
Any chromosomal	54 (2.6)	2045 (97.4)	0.96 (0.69–1.3)	0.86 (0.60–1.2)
Trisomy 21	34 (2.8)	1174 (97.2)	1.1 (0.71–1.6)	0.98 (0.64–1.5)
Trisomy 13	2 (1.8)	112 (98.2)	0.65 (0.16–2.7)	0.62 (0.15–2.6)
Trisomy 18	7 (3.5)	194 (96.5)	1.3 (0.60–2.8)	1.3 (0.54–3.1)[b]
Autosomal deletions	4 (2.5)	155 (97.5)	0.94 (0.34–2.6)	0.45 (0.05–1.7)
Balanced autosomal translocation	0 (0.0)	33 (100.0)	—	—
Other autosomal anomalies	4 (2.0)	197 (98.0)	0.74 (0.27–2.0)	0.54 (0.17–1.7)
Monosomy X variants	1 (0.9)	116 (99.1)	0.37 (0.05–2.7)	0.33 (0.05–2.4)
Klinefelter variants	3 (9.7)	28 (90.3)	3.4 (1.0–11.4)	4.5 (0.75–18.5)
Other sex chromosome anomalies	0 (0.0)	57 (100.0)	—	—

[a]Adjusted for maternal age, education, and race/ethnicity.
[b]Adjusted for child's sex and maternal age, education, race/ethnicity.

Table 3. Maternal residential proximity to industrial facilities and chromosomal anomalies in offspring

Group	Number (%) within 1 mile of facility	Number (%) ⩾1 mile from facility (referent)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio[a] (95% CI)
Controls	608 (13.9)	3760 (86.1)	—	—
Any chromosomal	312 (14.9)	1787 (85.1)	1.1 (0.93–1.3)	1.1 (0.92–1.3)
Trisomy 21	180 (14.9)	1028 (85.1)	1.1 (0.90–1.3)	1.1 (0.91–1.4)
Trisomy 13	19 (16.7)	95 (83.3)	1.2 (0.75–2.0)	1.2 (0.69–2.0)
Trisomy 18	25 (12.4)	176 (87.6)	0.88 (0.57–1.3)	1.1 (0.69–1.7)[b]
Autosomal deletions	34 (21.4)	125 (78.6)	1.7 (1.1–2.5)	1.5 (1.0–2.3)
Balanced autosomal translocation	5 (15.2)	28 (84.8)	1.1 (0.43–2.9)	1.2 (0.45–3.3)[c]
Other autosomal anomalies	29 (14.4)	172 (85.6)	1.0 (0.67–1.6)	1.1 (0.73–1.7)[c]
Monosomy X variants	15 (12.8)	102 (87.2)	0.86 (0.49–1.5)	0.82 (0.46–1.5)
Klinefelter syndrome	9 (29.0)	22 (71.0)	2.7 (1.2–5.9)	2.9 (1.1–7.3)
Other sex chromosome anomalies	4 (7.0)	53 (93.0)	0.47 (0.17–1.3)	0.49 (0.18–1.4)

[a]Adjusted for maternal age, education, and race/ethnicity.
[b]Adjusted for child's sex and maternal age, education, and race/ethnicity.
[c]Adjusted for maternal age, education, race/ethnicity, and public health region of residence.

or more from any industrial facility with reported chemical air emissions. Some effect modification by age was also noted for the association with residence near heavy metals emissions and chromosomal anomalies. Women 35 years or older who lived near facilities with reported emissions of heavy metals were more likely to have offspring with chromosomal anomalies (adjusted OR 2.0, 95% CI 1.1–4.1), and a similar pattern was noted for associations with trisomies 13, 18, or 21; monosomy X anomalies; Klinefelter variants; and other sex chromosomal anomalies.

Some effect modification by maternal age was also seen for proximity to industrial facilities and autosomal deletion syndromes. Relative to women living farther away in each respective age category, women who were either in the age groups 20–24 years or 30–34 years were over two times more likely to have offspring with these defects if they lived near industrial air emissions.

In the assessment of potential effects of excluding pregnancy terminations, we found stronger associations between maternal residential proximity to industrial facilities and chromosomal anomalies in offspring among women who received late (after the 4th month of pregnancy) or no prenatal care than among women who received prenatal care within the first 4 months of pregnancy. We noted the most marked differences in risk estimates for autosomal deletion syndromes. Among women with late or no prenatal care, those who lived within a mile of an industrial facility were 5.1 times more likely (95% CI 1.7–14.8) to have births with autosomal deletion syndromes than women who lived farther away. In contrast, we found no association (OR 1.0, 95% CI 0.63–1.7) between living near industrial facilities and autosomal deletion syndromes in offspring among women with prenatal care the first 4 months of pregnancy.

Table 4. Maternal residence within 1 mile of industrial facilities and selected chromosomal anomalies[a] by maternal age

Group	Maternal age (years)											
	<20		20–24		25–29		30–34		35–39		>39	
	Percent (%) living within one mile of industrial facility, odds ratios[b] (OR), and 95% confidence intervals (CI)											
	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)
Comparison births	16.8	—	14.2	—	15.1	—	11.3	—	11.1	—	6.8	—
Any chromosomal anomaly	13.2	0.74(0.48–1.1)	16.6	1.1(0.83–1.6)	15.9	1.0(0.72–1.4)	14.5	1.3(0.90–1.9)	13.0	1.1(0.68–1.6)	16.1	2.5(0.94–6.9)
Trisomy 21	14.8	0.81(0.46–1.4)	17.2	1.2(0.76–1.8)	17.2	1.1(0.71–1.6)	13.2	1.2(0.76–1.9)	12.9	1.1(0.64–1.7)	15.6	2.6(0.92–7.1)
Trisomy 18	6.3	0.33(0.04–2.5)	16.1	1.4(0.51–3.8)	8.8	0.71(0.21–2.4)	11.1	0.97(0.33–2.9)	11.5	1.1(0.43–2.8)	19.4	3.7(0.88–18)
Autosomal deletion syndromes	12.1	0.69(0.24–2.0)	30.0	2.3(1.1–4.9)	15.8	1.0(0.41–2.5)	26.5	2.9(1.3–6.7)	23.1	1.5(0.30–7.2)	0.0	—
Other autosomal anomalies	17.2	0.97(0.36–2.6)	16.1	0.99(0.44–2.3)	10.2	0.67(0.26–1.7)	17.2	1.8(0.66–5.1)	6.7	0.57(0.06–2.5)	30.0	3.7(0.44–40)

[a]Specific anomalies selected if most age categories contained three or more "exposed" case-mothers.
[b]Odds ratios adjusted for maternal education and race/ethnicity. Referent groups are women in each age category who lived 1 or more miles away from industrial facilities.

Discussion

In this population, women who lived near hazardous waste sites were not more likely to have births with chromosomal anomalies with the exception of Klinefelter variants among births to Hispanic women. Maternal residence near industrial facilities with reported air emissions, however, showed some relation to several types of chromosomal anomalies in offspring including autosomal deletion syndromes and Klinefelter variants. Moreover, advanced maternal age modified risk estimates for several anomalies, particularly if women lived near industries with air releases of heavy metals or solvents.

Selection of cases

Some bias might have been introduced in this study by not including pregnancy terminations (without vital records). Among controls, we found that women who lived near hazardous wastes sites and industrial facilities were more likely to be less educated and of a racial/ethnic group other than non-Hispanic white (Brender et al., 2006a). These populations might also have been less likely to have prenatal diagnosis of a defect. Timing of prenatal care did not vary by case–control status in this study; approximately 14% of case and control women received prenatal care after the 4th month or not at all. Earlier prenatal care and prenatal diagnosis can result in elective terminations of affected pregnancies, which are less likely to be ascertained by the TBDR. Furthermore, first trimester miscarriages due to chromosomal abnormalities are likely to be missed by the surveillance system because these events are frequently medically managed outside the hospital. It would therefore be expected that risk estimates for the association between living near industrial facilities and births with chromosomal anomalies, if real, might be higher among women who received later prenatal care than earlier prenatal care. This pattern was observed; risk estimates tended to be higher for several of the defects among women who received later or no prenatal care compared with women who received earlier prenatal care.

Classification of exposure status

This study used maternal addresses at delivery, which might have led to misclassification of exposure. For anomalies studied, the most appropriate residential exposure windows would include parental residences shortly before or at conception or even grandmaternal residence for some defects if the aberration occurred during maternal meiosis I. Previous studies have indicated that 20–25% of women move one or more times between conception and delivery (Khoury et al., 1988; Shaw and Malcoe, 1992). On the other hand, these studies including a recent one of Texas mothers (Canfield et al., 2006) found that older women were less likely to move during this period than younger women. Among the Texas participants in the National Birth Defects Prevention Study (NBDPS) (Yoon et al., 2001) with births during 1998–2001, comparable proportions of women moved one or more times during the periconceptional period (3 months before through 3 months postconception) among those who lived within a mile of an industrial facility or further away (37% vs. 36%). Women who lived near a hazardous waste site were somewhat more likely to move during this period (39%) than women who lived further away from such sites (36%).

In this study, we focused on maternal residences occurring with the index pregnancy, which is appropriate if the chromosomal aberration occurred shortly before or at conception. However, chromosomal damage might have occurred earlier and/or might have been the result of cumulative environmental exposures. Therefore, lifetime residential and exposure histories would have provided a more accurate assessment of the relation between residential proximity to sources of environmental pollution and chromosomal anomalies in offspring.

Misclassification of exposure may have also occurred in this study by using proximity of residence to waste sites and industrial facilities as a proxy for potential exposure to contaminants. Similar proportions of case and control maternal addresses were assigned geocodes so this misclassification is likely to be non-differential with respect to case or control status, thereby leading to risk estimates closer to the null. Although a distance of 1 mile was used in most analyses to define proximity, we also examined distances in finer categories from one-quarter mile up to 2 miles with more than 2 miles as the referent group. In a few instances, the OR were above 1.5 for distances greater than a mile from waste sites including those for autosomal deletion syndromes and other autosomal anomalies (1.50–1.74 miles), trisomy 13 (1.25–1.49 miles), and trisomy 18 (1.00–1.24 miles and 1.50–1.74 miles); numbers of exposed case women were sparse in these categories and the 95% confidence limits of the OR were consistent with unity.

Potential exposure to industrial air pollutants would also depend on prevailing wind direction, a factor that was not considered in the study. Although this added parameter might have reduced misclassification of exposure among women who lived near a single industrial facility, the designation of being upwind or downwind from the nearest industry with reported air emissions might have introduced additional misclassification among women who lived near several facilities. Among women in the study population who lived within 1 mile of an industry, approximately one-third lived near two or more facilities.

Findings in relation to other studies

Our findings of little or no association between maternal residence near hazardous waste sites and chromosomal anomalies differed from the results of several other studies. Among New York State live births, a residence at delivery within 1 mile of a hazardous waste site with "plastics" was associated with chromosomal anomalies in births (OR 1.5, 95% CI 1.0–2.1) (Geschwind et al., 1992). Although the waste sites in the present study were not classified by whether plastics were present, we had information regarding several of the contaminants of concern associated with plastics including butadiene and styrene. We found no association between living near waste sites with these contaminants or near industrial facilities with emissions of butadiene or styrene and chromosomal anomalies.

Studies may have differed in conclusions from using varying distances for defining "proximity of residence." For instance, in a study involving five European countries and 23 hazardous waste landfill sites, women who lived within 3 kilometers (km) (1.9 miles) relative to women living 3–7 km were 1.5 times more likely (95% CI 1.0–2.2) to have offspring with chromosomal anomalies (Vrijheid et al., 2002). We replicated these distances in our study population and found a slightly negative association between living near hazardous waste sites and chromosomal anomalies (OR 0.90, 95% CI 0.70–1.2). In a study of maternal residence near NPL waste sites and birth defects among California residents, women who lived in a census tract with one or more NPL sites were more likely to have births with trisomies 13 or 18 (OR for both 2.7) or with other sex chromosome anomalies (OR 3.1) (Orr et al., 2002). Because a 1-mile distance area usually encompasses less land area than a census tract, we expanded the distances to cover 2, 3, 4, and 5 miles areas in the present study. We found a slightly positive association between trisomy 18 and residential distances from NPL waste sites within 2 (OR 1.2), 3 (OR 1.3), 4 (OR 1.4), and 5 miles (OR 1.3) with the referent groups, respectively, as 2, 3, 4, or 5 or more miles from any waste site.

In this study, we included hazardous waste sites that were either NPL or state superfund sites. Because these sites were undergoing the process of assessment and remediation, the potential for uncontrolled releases was reduced. This discovery and containment process may account, in part, for the lack of association between a maternal residence near these waste sites and chromosomal anomalies in offspring. On the other hand, results from other studies (Ritz et al., 2002; Gilboa et al., 2005) have suggested an association between air pollutants and some types of heart defects; chromosomal anomalies without cardiac or oral cleft defects were not examined in these studies. The associations that we observed between maternal residence near industrial facilities and chromosomal anomalies in offspring, if real, might be due to point–source pollution from industries or ambient air pollution associated with vehicular emissions and industrial activities in areas with high population density.

Conclusion

Sufficient numbers of chromosomal anomalies allowed us to examine specific types of chromosomal anomalies in relation to hazardous waste sites and industrial facilities as well as the potentially modifying effects of advanced maternal age. Several of the associations found would have been missed by considering these anomalies as a single group or as "trisomy 21" and "other" chromosomal anomalies. While maternal proximity to hazardous waste sites was not related to specific chromosomal anomalies in this population with the exception of Klinefelter variants among Hispanic births, study findings suggest that residential proximity to industries with emissions of solvents or heavy metals might be associated with these anomalies in births to older mothers. Other studies have also found that older women might be more vulnerable than younger women to adverse reproductive outcomes if exposed to environmental contaminants (Sonnenfeld et al., 2001; Yauck et al., 2004). On the other hand, adverse effects from environmental exposures might be cumulative, especially with chromosomal anomalies, and might be better understood by studying such exposures throughout the women's reproductive years. Conversely, the recognized baseline increase in older women may reflect longitudinal exposures in all women.

Acknowledgments

This study was supported through the cooperative agreement U50/CCU613232 from the Centers for Disease Control and Prevention and contract 7547547549 from the Texas Department of State Health Services Center for Birth Defects Research and Prevention. The authors thank Wendy Marckwardt, Texas State University for her assistance in abstracting environmental data, Ionara Delima, Texas State University for geocoding industrial and maternal addresses, and Zunera Gilani, Texas Department of State Health Services for assistance with the birth files. They also thank Yaowen Han, Texas State University for providing computer programming expertise in the file linkages.

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