Matern Child Health J (2010) 14:625–634
DOI 10.1007/s10995-009-0492-z

Residential Mobility During Pregnancy: Patterns and Correlates

Assia Miller · Csaba Siffel · Adolfo Correa

Published online: 1 July 2009

Abstract Information on patterns and correlates of residential mobility can be important in studies of environmental factors and birth outcomes. The objective of this study was to describe residential mobility patterns and possible sociodemographic correlates of residential mobility among pregnant women. We obtained information on 656 mothers of infants with birth defects (cases) and 335 mothers of infants without birth defects (controls) from the geocoded dataset of the Birth Defects Risk Factor Surveillance Study, a case–control study conducted in Atlanta, Georgia, from 1993 through 1997. Using geographic information techniques, we measured distances mothers moved between residential addresses, and evaluated the proportion of moves and movement patterns by trimester. We used multivariate logistic regression to evaluate possible correlates of residential mobility for case and control mothers, including race, age, education, occupation, socioeconomic status, smoking, parity, and pregnancy planning. About 22% of women moved during pregnancy and most of them moved during the second trimester (11.9%), with no variation by case–control status. Among mothers who moved 51% moved within the same county. Pregnant women were more likely to move if they were younger (20–24 years, adjusted odds ratio (aOR) 3.39, 95% confidence interval (CI) 2.12–5.42; ≥30 years: reference), did not plan their pregnancy (aOR 1.66, 95% CI 1.18–2.34), and smoked (aOR 1.46, 95% CI 1.01–2.12). For these associations with mother's residential mobility, there were no appreciable confounding or effect modification effects by case–control status. In studies of pregnancy outcomes and potential environmental exposures based on residence at the time of delivery, residential mobility during pregnancy may not vary by case–control status, but it still needs to be considered as a possible source of exposure misclassification. Accounting for potential case–control differences in correlates of residential mobility could be useful in minimizing potential non-differential misclassification.

Keywords Residential mobility · Pregnancy · Birth defects · Surveillance · Geographic information systems (GIS) · Misclassification · Exposure

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A. Miller (✉) · C. Siffel · A. Correa
Division of Birth Defects and Developmental Disabilities, National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention, Mailstop E-86, 1600 Clifton Road, Atlanta, GA 30329, USA
e-mail: amiller@cdc.gov

A. Miller
Oak Ridge Institute for Science and Education, Oak Ridge, TN, USA

C. Siffel
Computer Sciences Corporation, Atlanta, GA, USA

Introduction

Retrospective studies of birth outcomes often rely on vital or medical records for ascertainment of information on maternal residence at the time of delivery. In evaluation of health effects on the fetus of various environmental exposures it would be ideal to use information on maternal residential addresses during pregnancy, since pregnant women spend the majority of their times at or near home [1]. For development of birth defects (structural malformations) the first trimester of pregnancy is considered the most critical period [2]. Because information on maternal residential addresses prior to delivery is usually not available, researchers often must use residential addresses at the time of delivery as a proxy for residential address and for assessment of potential environmental exposures during pregnancy, the implicit assumption being that residential mobility does not occur during pregnancy [3–7].

However, a few publications have indicated that approximately 12–31% of pregnant women move during their pregnancies [8–11] (Table 1). The use of maternal residence at the time of delivery for exposure assessment during pregnancy might result in exposure misclassification and biased estimates of associations [12]. For example, two subsequent studies based on California Birth Defects Monitoring Program data examined maternal residential proximity to hazardous waste sites and risk for selected congenital malformations [6, 13]. In the first study authors assigned exposure based on maternal residencies at delivery and reported reduced risk for central nervous system defects, and increased risk for heart malformations. In contrast, in the second study authors were able to assign exposure based on the maternal residence during early pregnancy and found an elevated risk for neural tube defects among women who lived within a ¼ mile of a

Table 1 Selected publications on residential mobility during pregnancy

Khoury et al. [9]	Shaw and Malcoe [10]	Canfield et al. [8]	Fell et al. [11]
Place			
United States	United States	United States	Canada
Maryland	California (one county)	Texas	Nova Scotia Eastern Ontario
Time			
1984	1981–1983	1997–2001	1999–2001
Design			
Cohort	Case–control	Case–control	Cohort
Participants			
295 (case infants)	152 (heart defects)	935 (birth defects)	398 (healthy controls)
	175 (controls)	297 (controls)	
Overall mobility			
20%	25%	31%	12%
Variables examined			
Maternal age	Maternal age	Maternal age	Maternal age
Maternal race	Maternal race	Maternal race/ ethnicity	Maternal education
Parity	Maternal education	Parity	Family income
Infant sex	Parental employment	Prenatal care	Marital status
Quarter of birth		Level of education	Employment status
Selected birth defects		Household income	Urban or rural location
		Maternal employment status	Month prenatal care began
		Rural/urban status	Parity
		Selected birth defects	Prepregnancy BMI
			Maternal illness, influenza
			Medication, folic acid use
			Exposure to pesticides or chemicals
			Smoking
			Exposure to secondary smoke
			Activity level
Correlates of mobility			
Younger maternal age	Maternal age <21 years	Maternal age <30 years	Prepregnancy BMI
White race	<High school graduates Whites/Hispanics	<2+ children (controls only)	Family income Maternal age <25 years

hazardous waste site. The variations in the exposure assessment due to use of address at delivery might attribute to imprecise risk estimation, which maybe was the case in the earlier study in California.

The extent of exposure misclassification due to residential mobility and the resultant bias are likely to be influenced by the patterns and correlates of residential movement. Thus far, only two studies have reported some limited information on patterns of movements among mothers who moved: one of the studies reported that 36% of mothers moved to a different county [9], and the other reported that 6% of mothers moved within the same census tract [10]. However, the previous studies did not use geocoded data and did not examine the distance of movement. Several maternal characteristics, including maternal age, maternal race, parity, maternal education, prepregnancy body mass index (BMI), and family income (Table 1), have been evaluated as possible predictors of residential mobility during pregnancy, with limited consistency found for possible correlates [8–11]. In an effort to account for possible exposure misclassification in retrospective studies of pregnancy outcome where exposure assessment is based on maternal residence at the time of birth, it becomes important to determine whether there are some consistent correlates of mobility, and particularly whether such mobility is likely to vary by case–control status. However, only two epidemiologic studies examined variation in mobility by case–control status [8, 10] and the study that examined a broad range of correlates of mobility was based on healthy controls [11]. Therefore, information on residential mobility and correlates is limited.

We examined data from a case–control study of birth defects in Atlanta, Georgia, to: (1) describe residential mobility patterns of mothers during pregnancy in a different population than has been published in recent years; and (2) evaluate a broader range of possible sociodemographic correlates for residential mobility.

Methods

Data Source

We used data from the Atlanta Birth Defects Risk Factor Surveillance Study (BDRFS), a case–control study of risk factors for birth defects conducted during 1993–1997 [14]. BDRFS included case liveborn and stillborn infants with selected major defects identified through the Metropolitan Atlanta Congenital Defects Program (MACDP), a population-based birth defects registry that actively monitors major birth defects among affected infants and fetuses born to residents of the five central counties of metropolitan Atlanta [15]. Because the goal of the study was to identify causes of birth defects, defects of known etiology (such as single-gene conditions and chromosomal anomalies) were excluded from BDRFS. However, defects associated with conditions presumed to be related to maternal exposure to a teratogen (such as maternal diabetes or anticonvulsant exposure) were included in order to study genetic factors that potentially modify teratogenic effects. Each case infant was classified as having isolated (only one major primary malformation) or multiple (two or more major unrelated malformations) defects following a recognized case classification approach [16]. All isolated case infants were grouped into one of the following nine birth defect groups: neural tube defects (NTDs), central and peripheral nervous system defects (not including NTDs), orofacial clefts, heart defects, respiratory system defects, digestive system defects, genitourinary system defects, and musculoskeletal system defects.

Control infants were a stratified random sample of births at the 18 birth hospitals from which the case infants were ascertained, with the number of control infants selected from each hospital proportional to the distribution of all metropolitan Atlanta births by hospital. Control infants were selected among births during the same time period as case infants, and were limited to infants without major birth defects.

BDRFS collected data on case and control infants through a telephone survey conducted in English or Spanish. Data collected included information on maternal health, medication use, pregnancy history and fertility, demographics, family history, nutrition, occupational and environmental exposures, tobacco and alcohol use, and substance abuse.

Sixty-six percent of eligible mothers participated in the interview. After excluding records with missing or incomplete information (for 11 case and 5 control infants), our final sample comprised 991 records (656 case and 335 control infants).

Residential Mobility Definition, Patterns, and Distances

The BDRFS ascertained a complete residential history, from 3 months before conception through delivery. We used ArcGIS 9.1, a geographic information systems (GIS) software to obtain spatial coordinates (geocodes) for all residential addresses [17]. Although the term "mobility" often refers to any change of permanent address [18], we considered mobility in a broader sense. Women who changed their location (address) at least once during the period from 3 months before conception to delivery were considered as "mobile", regardless of whether it was a temporary or permanent change of residence. In our study, we made an effort to describe mothers' mobility patterns by trimester. A minimum of 4 weeks at a residence was required for a location change to be counted as a move. The numbers of changes of residences were calculated for mothers of case and control infants who moved at different times during the period of about 12 months: 3 months before conception to the date of delivery. We counted mothers who moved at least once during the following time periods: from 3 months before conception to delivery, from 3 months prior to conception to conception, from conception to delivery, and at least once in each trimester during the pregnancy. To describe the pattern of mobility, we calculated nonexclusive occurrences so that mothers who moved more than once within a time period were counted multiple times.

We investigated movement patterns and actual distances mothers moved. To examine movement patterns from the date of conception to the date of delivery, we grouped location change based on the county of residence, whether the mother changed her residence by moving: (1) within the same county (intracounty); (2) between different counties in metropolitan Atlanta area (intercounty); or (3) into the metropolitan Atlanta area from any other location.

We calculated the distance between geographic coordinates of addresses of each movement by the mother by applying a spherical model [19]. We then categorized distances in miles by quartiles: <3 miles, 3 to <8 miles, 8 to <24 miles, and ≥24 miles.

Covariates

We estimated the date of conception based on gestational age at delivery, which was based on maternal self-report. As possible correlates of residential mobility, we considered covariates examined in previous studies [8–11]: maternal race (White, Black or African American, or other), maternal and paternal age (<20, 20–24, 25–29, or ≥30 years), parity (nulliparous or one birth, or two or more births), maternal and paternal education level (<high school, high school, or ≥college), prepregnancy body mass index (BMI) (<25 or ≥25), alcohol consumption during pregnancy (yes or no), smoking during pregnancy (yes or no), planning of pregnancy (yes or no), and type of employment. Prepregnancy BMI was based on the mother's self-reported height and prepregnancy weight, and was calculated as weight (in kilograms) divided by height (in meters) squared, and was dichotomized: normal or below normal weight ($BMI < 25.0$), and above normal weight (overweight or obese) ($BMI \geq 25.0$). We classified the self-reported maternal jobs, including any part-time or full-time job during the period 3 months prior to pregnancy to delivery, using the occupational codes listed in the 1990 Census Industrial and Occupational Classification Codes [20] into four broad occupational categories: (1) managerial and professional specialty occupations (managerial); (2) technical, sales, administrative support (technical or sales), and service occupations (service); and (3) farming and other, which included the categories farming, forestry, fishing, precision production, craft and repair occupations, operators, fabricators, and laborers. We grouped the categories homemaker, parent, student, and disabled into the category "unemployed".

We assigned a socioeconomic status (SES) indicator to case and control mothers based on the percentage of people living below the federally defined poverty line as defined in the 1990 and 2000 U.S. Census data [21] in the mother's census tract at the time of conception and according to the Public Health Disparities Geocoding Project [22]: (1) if less than 5% of people living in a given census tract were living in poverty the mother whose address at the time of conception was located in that tract was considered to have a high SES; (2) if 5.0–9.9%, a middle to high SES; (3) if 10.0–19.9%, a middle to low SES; and (4) if ≥20%, a low SES.

Statistical Analysis

Participants who moved at least once between the date of conception and date of delivery were compared with participants who did not move during their pregnancy. Analysis by trimester was not possible due to small numbers. The relative odds of moving in relation to a given covariate and its 95% confidence interval (CI) were estimated using logistic regression. Variables found to be associated with moving in unadjusted analyses were selected for inclusion in a multivariable logistic regression model. We conducted logistic regression analyses with and also without stratification on the case–control status of the study participants. All the analyses were conducted using SAS version 9.01 [23].

Results

Of the 991 case and control mothers, 253 (26%) moved at least once from 3 months prior to conception to delivery, and 22% moved during the period from the date of conception to the date of delivery (Fig. 1). The majority of pregnant women (11.9%) moved during the second trimester. There was no appreciable variation in residential mobility by case–control status and by defect group among case mothers (Fig. 2). Seventy (48%) case infants were prenatally diagnosed with a birth defect.

With respect to distance moved, 41.8% of case mothers and 41.1% of control mothers moved less than 8 miles (Table 2). Among case and control mothers who moved during pregnancy, the majority moved intracounty (50.7% and 52.1%, respectively) versus intercounty (23.3% and 23.3%, respectively), or moved into the metropolitan

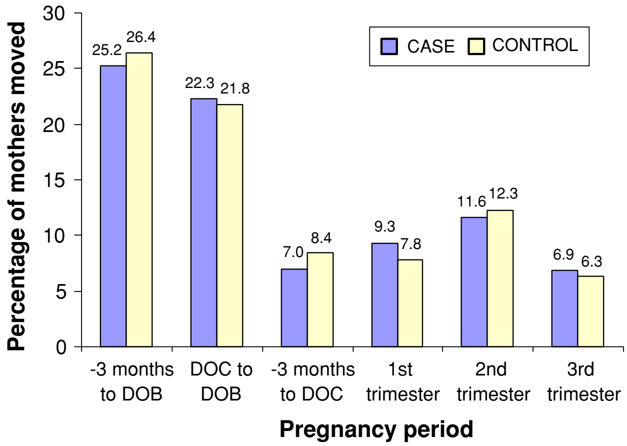

Fig. 1 Residential mobility among case and control mothers, any time from 3 months prior to conception to delivery, and by pregnancy period, Birth Defects Risk Factor Surveillance Study, 1993–1997. *DOC* date of conception, *DOB* date of birth. Mothers who moved more than once between and within trimesters are double or triple counted

Atlanta area (26.0% and 24.7%, respectively) (Table 2). Among those mothers who moved, 24% of mothers moved two or more times (data not shown).

In unadjusted analyses, among all mothers maternal age was significantly associated with maternal mobility (Table 3). Mothers who were 20–24 years of age had a greater than a three-fold increase in the likelihood of moving (OR 3.24; 95% CI [2.10, 5.01]) compared with mothers who were 30 years of age or older. Mothers living in a census tract with a mid-low or higher SES were two times more likely to have moved than mothers living in a low SES census tract (OR 2.32; 95% CI [1.21, 4.44]). Women who were nulliparous or reported having given birth to only one child previously were more likely to have moved (OR 1.48; 95% CI [1.10, 2.01]) than women who reported having given birth to two or more children. Mothers who smoked any time during pregnancy were more likely to have moved (OR 1.64; 95% CI [1.15, 2.35]) than mothers who did not smoke. We also found that

Fig. 2 Maternal mobility by birth defect group, Birth Defects Risk Factor Surveillance Study, 1993–1997. *NTD* neural tube defect, *CNS* central nervous system. Mothers who had infants with more than one defect are double or triple counted

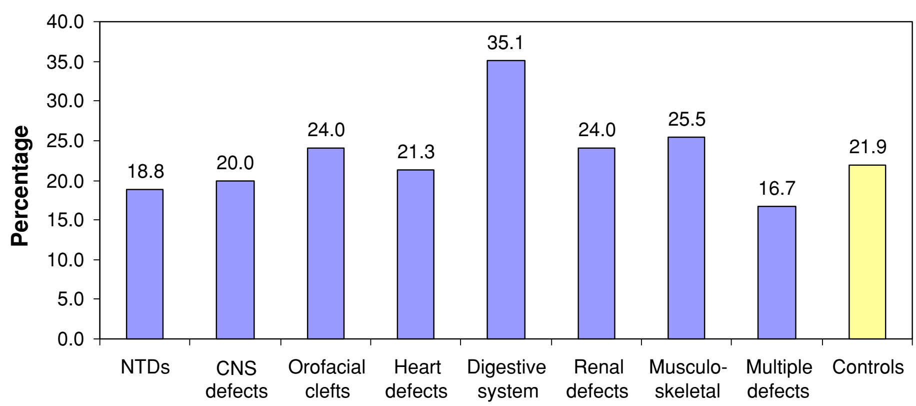

Table 2 Distance and direction of location change among case and control mothers between date of conception and date of birth, Birth Defects Risk Factor Surveillance Study, 1993–1997

Location change	Case mother moved		Control mother moved		Total moved	
	No.	%	No.	%	No.	%
Distance[a]						
<3 miles	33	22.6	12	16.4	45	20.5
3 to <8 miles	28	19.2	18	24.7	46	21.0
8 to <24 miles	28	19.2	16	21.9	44	20.1
≥24 miles	27	18.5	17	23.3	44	20.1
Not available	30	20.5	10	13.7	40	18.3
Direction of movement						
Intracounty	74	50.7	38	52.1	112	51.1
Intercounty (within metropolitan Atlanta)	34	23.3	17	23.3	51	23.3
Moved into metropolitan Atlanta	38	26.0	18	24.7	56	25.6
Total	146	22.3	73	21.9	219	100.0

[a] Distances categorized in miles by quartiles

Table 3 Characteristics of movers and nonmovers, by case and control status, BDRFS, 1993–1997

Characteristics	All mothers		Case mothers moved		Control mothers moved	
	No. in stratum (%)	Crude OR	No. in stratum (%)	Crude OR	No. in stratum (%)	Crude OR
Maternal age (years)[a]						
<20	110 (11.1)	2.16 (1.34–3.48)	24 (31.6)	2.70 (1.53–4.78)	7 (20.6)	1.27 (0.51–3.19)
20–24	124 (12.6)	3.24 (2.10–5.01)	30 (36.1)	3.31 (1.93–5.69)	16 (39.0)	3.14 (1.50–6.57)
25–29	240 (24.3)	2.00 (1.35–2.84)	43 (27.0)	2.17 (1.37–3.45)	20 (24.7)	1.61 (0.85–3.05)
≥30	513 (52.0)	1.00	49 (14.6)	1.00	30 (17.0)	1.00
Maternal race						
Other	103 (10.4)	1.33 (0.82–2.16)	17 (24.6)	1.36 (0.74–2.48)	10 (29.4)	1.29 (0.57–2.90)
Black or African American	319 (32.3)	1.11 (0.80–1.55)	55 (27.0)	1.53 (1.03–2.30)	18 (15.7)	0.57 (0.31–1.05)
White	565 (57.2)	1.00	74 (19.4)	1.00	45 (24.5)	1.00
Socioeconomic status						
High	405 (41.3)	1.88 (1.02–3.45)	58 (21.1)	1.48 (0.73–3.00)	32 (24.6)	3.37 (0.97–11.78)
Mid-high	281 (28.7)	1.94 (1.04–3.63)	45 (24.2)	1.77 (0.86–3.65)	19 (20.0)	2.58 (0.71–9.35)
Mid-low	188 (19.2)	2.32 (1.21–4.44)	30 (26.3)	1.98 (0.92–4.26)	18 (24.7)	3.38 (0.92–12.39)
Low	106 (10.8)	1.00	11 (15.3)	1.00	3 (8.8)	1.00
Parity						
Nulliparous or one birth	427 (43.1)	1.48 (1.10–2.01)	69 (25.5)	1.37 (0.94–1.98)	42 (26.9)	1.76 (1.04–2.97)
≥2 births	564 (56.9)	1.00	77 (20.0)	1.00	31 (17.3)	1.00
Maternal education						
<High school	126 (12.8)	1.33 (0.86–2.06)	26 (27.4)	1.41 (0.85–2.34)	8 (25.8)	1.17 (0.50–2.77)
High school	203 (20.6)	0.94 (0.64–1.38)	31 (22.6)	1.09 (0.69–1.74)	11 (16.7)	0.67 (0.33–1.38)
≥College	658 (66.7)	1.00	89 (21.1)	1.00	54 (22.9)	1.00
Maternal occupation						
Managerial	264 (26.6)	0.73 (0.47–1.14)	28 (17.0)	0.79 (0.46–1.38)	16 (16.2)	0.63 (0.30–1.32)
Technical, sales	312 (31.5)	1.20 (0.81–1.80)	49 (23.9)	1.22 (0.75–1.99)	28 (26.2)	1.16 (0.60–2.26)
Service	119 (12.0)	1.53 (0.93–2.51)	28 (31.5)	1.78 (1.00–3.25)	7 (23.3)	0.99 (0.37–2.67)
Farming, other	44 (4.5)	0.94 (0.43–2.08)	6 (23.1)	1.17 (0.44–3.12)	3 (16.7)	0.65 (0.17–2.50)
Unemployed	252 (25.4)	1.00	35 (20.5)	1.00	19 (23.5)	1.00
Prepregnancy BMI						
<25	694 (70.0)	0.96 (0.70–1.33)	98 (21.8)	0.92 (0.62–1.36)	54 (22.1)	1.08 (0.60–1.94)
≥25	297 (30.0)	1.00	48 (23.3)	1.00	19 (20.9)	1.00
Maternal alcohol consumption						
Yes	487 (49.1)	1.28 (0.94–1.72)	67 (20.3)	0.80 (0.55–1.15)	34 (19.5)	0.76 (0.45–1.28)
No	504 (50.9)	1.00	79 (24.2)	1.00	39 (24.2)	1.00
Maternal smoking						
Yes	186 (18.8)	1.64 (1.15–2.35)	108 (20.7)	1.55 (1.01–2.40)	56 (19.9)	1.85 (0.97–3.52)
No	804 (81.2)	1.00	38 (28.8)	1.00	17 (31.5)	1.00
Planned pregnancy[a]						
No	580 (58.8)	1.78 (1.30–2.46)	96 (26.3)	1.74 (1.18–2.56)	55 (25.6)	1.91 (1.06–3.43)
Yes	406 (41.2)	1.00	49 (17.0)	1.00	18 (15.3)	1.00
Paternal age (years)[a]						
<20	46 (4.8)	1.89 (0.94–3.78)	8 (25.0)	1.78 (0.76–4.13)	4 (28.6)	2.16 (0.64–7.31)
20–24	109 (11.4)	4.05 (2.61–6.28)	32 (47.1)	4.74 (2.74–8.18)	15 (36.6)	3.11 (1.48–6.53)
25–29	197 (20.6)	2.40 (1.65–3.48)	40 (31.3)	2.42 (1.53–3.83)	21 (30.4)	2.36 (1.24–4.47)
≥30	603 (63.1)	1.00	64 (15.8)	1.00	31 (15.7)	1.00
Paternal education						
<High school	102 (10.7)	1.56 (0.98–2.50)	20 (27.0)	1.37 (0.78–2.42)	10 (35.7)	2.17 (0.92–4.95)

Table 3 continued

Characteristics	All mothers		Case mothers moved		Control mothers moved	
	No. in stratum (%)	Crude OR	No. in stratum (%)	Crude OR	No. in stratum (%)	Crude OR
High school	253 (26.4)	1.14 (0.80–1.62)	41 (23.8)	1.16 (0.75–1.77)	18 (22.5)	1.10 (0.60–2.04)
≥College	603 (62.9)	1.00	82 (21.3)	1.00	45 (20.6)	1.00

OR odds ratio, *CI* confidence interval

[a] Numbers might not add to total because of missing data

mothers who had not planned their pregnancy were more likely to have moved (OR 1.78; 95% CI [1.30, 2.46]) than mothers who intended to become pregnant. Fathers who were 20–24 years of age were four times more likely to have moved (OR 4.05; 95% CI [2.61, 6.28]) than fathers who were 30 years of age or older. Analysis stratified by case–control status did not reveal significant differences in the likelihood of moving between case and control mothers. Movement and location change did not vary significantly among various defect groups (data not shown).

Based on an adjusted logistic regression model, we found that mothers were more likely to have moved if they were younger (20–24 years of age) (aOR 3.39; 95% CI [2.12, 5.42]); lived in high SES census tracts (aOR 3.28; 95% CI [1.69, 6.36]); smoked (aOR 1.46; 95% CI [1.01, 2.12]); and did not plan their pregnancy (aOR 1.66; 95% CI [1.18, 2.34]) (Table 4).

Discussion

We found that about 22% of pregnant women changed their residence from the date of conception to delivery in metropolitan Atlanta. The majority of residential changes occurred within one county (intracounty moves). Women who moved differed from those who did not, by maternal age, SES, smoking during pregnancy, and pregnancy planning, yet there were no meaningful differences in the characteristics of movers and nonmovers between case and control mothers.

Our findings regarding the proportion of women who moved, the timing during pregnancy of such moves, and moves within the same county were consistent with some of the observations cited previously [8, 9]. We observed a higher overall mobility rate than that reported by the Canadian study (22% vs. 12%, respectively) that might

Table 4 Odds ratios for change of location adjusted for maternal age, socioeconomic status, parity, maternal smoking, and planned pregnancy, Birth Defects Risk Factor Surveillance Study, 1993–1997

Characteristics	Total no. in stratum (%)	Mothers moved		
		No. in stratum (%)	Adjusted OR	95% CI
Maternal age (years)[a]				
<20	110 (11.1)	31 (28.2)	1.94	1.13–3.35
20–24	124 (12.6)	46 (37.1)	3.39	2.12–5.42
25–29	240 (24.3)	63 (26.3)	1.87	1.27–2.76
≥30	513 (52.0)	79 (15.4)	1.00	
Socioeconomic status				
High	391 (39.8)	90 (22.2)	3.28	1.69–6.36
Mid-high	282 (28.7)	64 (22.8)	2.82	1.44–5.51
Mid-low	191 (19.5)	49 (26.1)	2.96	1.49–5.88
Low	118 (12.0)	14 (13.2)	1.00	
Parity				
Nulliparous or one birth	427 (43.1)	111 (26.1)	1.31	0.95–1.82
≥2 births	564 (56.9)	108 (19.2)	1.00	
Maternal smoking				
Yes	186 (18.8)	55 (29.6)	1.46	1.01–2.12
No	804 (81.2)	164 (20.5)	1.00	
Planned pregnancy[a]				
No	580 (58.8)	151 (26.1)	1.66	1.18–2.34
Yes	406 (41.2)	67 (16.5)	1.00	

OR odds ratio, *CI* confidence interval

[a] Numbers might not add to total because of missing data

have been attributed to the geographic, economic, and social differences between the United States and Canada [11]. However, intercounty movement (23.3%) was lower than reported before [9]. Based on our geocoded dataset, we were able to demonstrate that the actual distance moved was within 24 miles about 75% of the time. There was no evidence of variation in movement by the type of defects present. This observation was also consistent with those of previous reports [8, 9]. It suggests that to the extent that prenatal diagnosis occurred among this population (nearly 50% of case mothers), it had little effect on the likelihood of a change of residence.

Our findings demonstrated that women who moved during pregnancy were different from women who did not move during pregnancy. In our study, maternal age, SES, smoking during pregnancy, and pregnancy planning were associated with the likelihood of moving; younger maternal age was one of the strongest correlates of mobility, as suggested by earlier reports [8–11].

Our findings showed a significant relationship between mobility during pregnancy and younger maternal age and smoking. Four other studies have also found younger maternal age to be associated with moving [8–11]. In the general US population, the highest moving rates are seen among young adults (20–29 year olds) [24]. Some of the reasons that the mobility rate is higher among young mothers are because they are more likely to be renters than house owners, more likely to have smaller families, and more likely to be enrolled in college or just graduated from college and looking for jobs. Worth noting is that young maternal age is correlated with smoking [25] and that smoking has been suggested to be associated with oral clefts and some other types of birth defects [26, 27]. Although in our study we did not find an association between residential mobility and case–control status, we can not definitely rule out a differential mobility rate during pregnancy.

The analysis of SES suggested that women living in higher SES census tracts were more likely to move than women living in lower SES census tracts. This result was different from the findings in the Canadian study [11]. The Canadian study found that women with lower income levels were more inclined to move than women with higher income levels. One possible reason offered for the higher mobility among lower income women in Canada was economic instability [11]; that is, residential mobility was motivated by economic needs, such as a better job or less expensive housing. The possible reasons for the higher mobility among women with higher SES compared with women with lower SES in Atlanta are unclear but could have been motivated by a need for a larger residence.

One variable that we found to be associated with a greater likelihood of moving, and which had not been reported on before, was whether or not the pregnancy was planned. We found that women who reported that their pregnancy was planned were less likely to move during pregnancy than women who did not plan their pregnancy. This finding was consistent with the idea that planning a pregnancy might be associated with behaviors that correlate with avoiding exposures that might affect the health status of the pregnancy [28].

Our findings must be viewed in light of the potential strengths and limitations of the study. Our study included all liveborn and stillborn infants with birth defects ascertained by an active surveillance system among a well-defined population. The case and control records had detailed residential histories during pregnancy. One of the advantages of our study was a relatively large sample size, because place of residency included a larger geographic area and covered a more recent time period than did previous studies. We could calculate the actual distance mothers moved using our geocoded addresses for all locations reported during the period from 3 months before the date of conception to the date of delivery.

A recent publication suggested that, among the general population, the odds of moving were higher among people with mental disorders than among a healthy control population or among people with greater numbers of hospitalizations and physician visits [29]. It is possible that pregnant women who had mental disorders, were substance abusers, or were victims of domestic violence were not included in our study because they did not have a stable residence or telephone service, or because they refused to participate in a 1.5-h interview. Because our study interviewed only English- or Spanish-speaking mothers, women who could not communicate in either of these two languages were not evaluated. Another limitation was that women who moved out of metropolitan Atlanta were not captured. Inclusion of these women would have given us more accurate estimates of women who moved during pregnancy. An additional limitation of our study was that the gestational age of the pregnancy, BMI, smoking, alcohol consumption, occupation, and residence change were based on self-reports, which are subject to recall errors. We also lacked information on other factors that might have had some influence on the likelihood of moving during pregnancy, such as illicit drug use, access to health insurance, and geographic proximity to a prenatal care facility and delivery hospital. Data we used were collected a decade ago, so our findings may not reflect current patterns of mobility among pregnant mothers.

One implication for future retrospective studies of pregnancy outcomes and prenatal environmental factors, in which exposure assessment is based on maternal residence at the time of delivery, is that it will be important to acknowledge or account for (whenever possible) potential

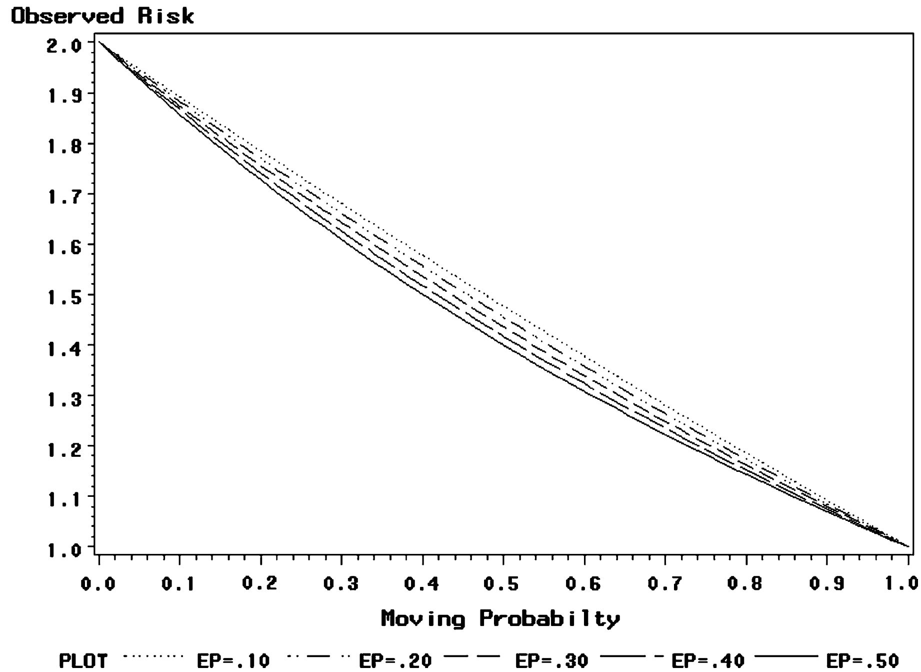

Fig. 3 Observed relative risk as a function of true risk, exposure probability and mobility for true relative risk = 2. *EP* exposure probability

nondifferential exposure misclassification that might result from residential mobility during pregnancy. Given that such misclassification can cause the relative risk of disease associated with the exposure in the population to be biased toward the null value [30], we examined its influence on association between exposure and birth defects. In Fig. 3, we illustrated the variation in the observed risk given 0.10, 0.20, 0.30, 0.40, and 0.50 probabilities of exposure in the general population in relation to probability of moving (residential mobility) assuming a true relative risk of 2.0. The figure shows the inverse association between mobility, probability of exposure and observed relative risk: the higher the moving probability and probability of exposure is, the lower the observed relative risk is compared with the true relative risk. If the moving probability is 0.2 (i.e., approximately 20% of mothers move during pregnancy) and the probability of exposure is 0.1, then the observed relative risk is equal to 1.8. Thus, the observed risk is biased toward the null value as the probability of exposure increases. This illustration suggests that for non-differential misclassification, use of residence at the time of birth to assess environmental exposures at the time of conception might lead to underestimation of true impact of environmental teratogen.

Residential mobility in Atlanta appeared to be associated with a number of maternal factors (e.g., maternal age, SES, and smoking) that also might have been associated with environmental exposures and outcomes of interest. Because some covariates of mobility, such as smoking, are also known risk factors for certain birth defects, it will be important to account for potential confounding by such maternal factors. Because our findings are not generalizable to other communities, further studies in other populations might be warranted to document the extent to which residential mobility occurs during pregnancy, and the factors associated with such mobility. In addition, studies are needed on the potential effect of such mobility on the uncertainty of point estimates of effect measures in studies of pregnancy outcomes and prenatal environmental exposures imputed from residence at the time of delivery.

Acknowledgments We thank the Metropolitan Atlanta Congenital Defects Program abstractors for their conscientious and skilled data collection efforts, and Bennett R. Gardner, C.J. Alverson, and Sheree Boulet for their assistance with manuscript preparation.

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