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Exposure misclassification due to residential mobility during pregnancy

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ABSTRACT

Objectives: Pregnant women are a highly mobile group, yet studies suggest exposure error due to migration in pregnancy is minimal. We aimed to investigate the impact of maternal residential mobility on exposure to environmental variables (urban fabric, roads and air pollution (PM10 and NO_2)) and socio-economic factors (deprivation) that varied spatially and temporally.
Methods: We used data on residential histories for deliveries at ≥24 weeks gestation recorded by the Northern Congenital Abnormality Survey, 2000–2008 ($n = 5399$) to compare: (a) exposure at conception assigned to maternal postcode at delivery versus maternal postcode at conception, and (b) exposure at conception assigned to maternal postcode at delivery versus mean exposure based on residences throughout pregnancy.
Results: In this population, 24.4% of women moved during pregnancy. Depending on the exposure variable assessed, 1–12% of women overall were assigned an exposure at delivery >1SD different to that at conception, and 2–25% assigned an exposure at delivery >1SD different to the mean exposure throughout pregnancy.
Conclusions: To meaningfully explore the subtle associations between environmental exposures and health, consideration must be given to error introduced by residential mobility.

Introduction

Epidemiological studies carried out at the ecological level, or using routinely collected health data, often assign exposure to an individual's residence at a single time point, such as birth, hospitalisation or death. This approach fails to account for individuals who might have migrated into or out of the population or for periodic spells away from a residence where levels of exposure are likely to be different from those experienced at home. Such migrations could result in exposure error or misclassification, reduced study power, and may result in biased risk estimates (Armstrong, 1998; Blair et al., 2007; Khoury et al., 1988).

Many environmental epidemiological studies of birth outcomes assign a measure of exposure based on maternal residential location at delivery because this information is readily available. The relatively short period between exposure and disease manifestation should mean that studies on congenital anomalies are less prone to migration bias, as there is less time in which the population can migrate. However, there is now a significant body of literature showing that pregnant women are a highly mobile group, with 10–30% of women moving residence during pregnancy (Bell and Belanger, 2012; Canfield et al., 2006; Fell et al., 2004; Hodgson et al., 2009; Khoury et al., 1988; Shaw and Malcoe, 1992; Zender et al., 2001).

Theoretical papers on the implications of residential mobility during pregnancy on the ability to detect environmental teratogens (Khoury et al., 1988) and impacts of differential mobility (Schulman et al., 1993) remain relevant, and a study showing the impact of mobility on real-life exposure scenarios and on

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environmental risk factors likely to confer small, but important increases in risk, is overdue. In this paper we investigate the impact of residential mobility during pregnancy on the measurement of exposure to a range of environmental factors previously explored in aetiological research (for example area-level measures of deprivation (Dibben et al., 2006; Janevic et al., 2010), land cover (e.g. urban/rural classifications) (Hillemeier et al., 2007; Langlois et al., 2010), road density/proximity to roads (Yorifuji et al., 2011) and air pollutants (Dugandzic et al., 2006; Hansen et al., 2009; Xu et al., 2011)), and quantify the exposure error likely to be introduced into a study reliant on maternal residential location at delivery as a proxy for residential location at conception and throughout pregnancy.

Materials and methods

The Northern Congenital Abnormality Survey (NorCAS) is a prospective, population-based registry covering the former UK northern health region, which includes north east England and north Cumbria (Fig. 1). This region comprises a population of about three million, with approximately 32,000 births each year over the study period 2000–2008, of which approximately 826 births each year (2.6%) included a major congenital anomaly and were therefore recorded in NorCAS. Data are collected on congenital anomalies occurring in late miscarriages (>20 weeks gestation), in live births and stillbirths, and in terminations of pregnancy for foetal anomaly after prenatal diagnosis at any gestation. The NorCAS follows the European Surveillance of Congenital Anomalies guidelines for inclusion on the register and classification of anomalies (see http://www.eurocat-network.eu/content/EUROCAT-Guide-1.3-Chapter-3.3-Jan2012.pdf) and codes anomalies according to the WHO International Classification of Diseases version 10. Cases are reported to the register from multiple sources to ensure a high case ascertainment, as described previously (Boyd et al., 2005; Richmond and Atkins, 2005). For this study, data on all pregnancies with a congenital anomaly delivered between 01 January 2000 and 31 December 2008 were extracted from NorCAS, although this dataset was subsequently restricted to those with a gestation at delivery of ≥24 weeks (a viable delivery), to allow better comparison with pregnancies resulting in a healthy delivery. If more than one baby in a multiple pregnancy has a congenital anomaly, each case is included on NorCAS. However, for this study, the pregnancy was counted as the 'case' so each pregnancy was counted only once.

The NorCAS contains addresses for women at both booking appointment (average gestational age 13 weeks in the UK) and delivery. To obtain more detailed information on residential history, the NorCAS data were linked to the UK National Health Service National Strategic Tracing Service records. Linkage was achieved using several data fields, including the mother's date of birth, National Health Service number, surname and residential postcode. Address at delivery was confirmed and updated as required. Date of conception was calculated from the date and gestation at booking (available within the NorCAS), and address details at this date, as well as any other residences during the index pregnancy (with dates of when the women moved to and from this address) available from the National Strategic Tracing Service were extracted to provide address at conception, and enable residential history throughout pregnancy to be established. All addresses were geocoded based on the address postcode centroid, the geographic centre of a collection of approximately 15 adjacent households making up the postcode. Within the study area the average distance between nearest neighbouring postcodes was 104 m, max 6.2 km, though this distance varied considerably between urban and rural areas (for example, in Newcastle Local Authority (a predominantly urban area) the average distance was 49 m, max 1.16 km, in contrast in Tynedale (rural authority) the average distance was 255 m, max 7.95 km). Grid references were obtained from the Office for National Statistics Postcode Directory (http://edina.ac.uk/ukborders/).

To establish the impact of residential mobility during pregnancy on exposure classification, we assigned to each woman's postcode at delivery and conception a measure of exposure to a variety of environmental factors, and, based on residential history, a measure of mean exposure throughout pregnancy weighted according to proportion of the pregnancy spent at each postcode. These variables include typical environmental factors explored in aetiological epidemiological research. We deliberately chose factors that were (a) readily available, (b) varied in terms of their spatial and/or temporal resolution, and (c) able to be assigned at the individual and/or area level. These variables are described in Table 1.

For deprivation, we used the 2007 Index of Multiple Deprivation, which comprises 38 indicators of deprivation spread across seven domains (income deprivation; employment deprivation; health deprivation and disability; education, skills and training

Table 1
Social and environmental variables assigned to maternal residential postcodes to explore the impact of residential mobility during pregnancy on characterisation of exposure.

Socio-economic status	
1. Index of Multiple Deprivation at Super Output Area level	
Data source	Office for National Statistics
Variable type	Continuous and quintile, area level
Spatial resolution	Super Output Area
Temporal resolution	n/a (data for 2007 used for whole study period)
2. Index of Multiple Deprivation at Local Authority level	
Data source	Office for National Statistics
Variable type	Continuous and quintile, area level
Spatial resolution	Local Authority
Temporal resolution	n/a (data for 2007 used for whole study period)
Land cover	
3. % Continuous Urban Fabric within 500 m buffer of postcode	
Data source	CORINE land cover 2000v8[a]
Variable type	Continuous and dichotomous, individual level
Spatial resolution	100 m
Temporal resolution	n/a (data from 2000 used for whole study period)
4. % Discontinuous Urban Fabric within 500 m buffer of postcode	
Data source	CORINE land cover 2000v8[a]
Variable type	Continuous and quintile, individual level
Spatial resolution	100 m
Temporal resolution	n/a (data from 2000 used for whole study period)
Roads	
5. Total length (m) of roads (motorways, A and B roads) within 500 m buffer of postcode	
Data source	Strategi 2011[b]
Variable type	Continuous and quintile, individual level
Spatial resolution	1 m
Temporal resolution	n/a (data from 2011 used for whole study period)
Air pollution	
6. Annual background PM10	
Data source	DEFRA Ambient Air Quality Assessment (UKAAQA)[c]
Variable type	Continuous and quintile, individual level
Spatial resolution	1 km grid square
Temporal resolution	Annual mean, 2001–2008
7. Daily NO_2	
Data source	DEFRA Automatic Urban and Rural Network[d]
Variable type	Continuous and quintile, individual level
Spatial resolution	Nearest monitor (for those living within 15 km of a monitor)
Temporal resolution	Daily mean (averaged over first trimester), 2000–2008

[a] http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-clc2000-100-m-version-8-2005.
[b] www.ordnancesurvey.co.uk/oswebsite/docs/user-guides/strategi-user-guide.pdf.
[c] http://uk-air.defra.gov.uk/data/pcm-data.
[d] http://uk-air.defra.gov.uk/networks/network-info?view=aurn.