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The effect of socio-environmental mechanisms on deteriorating respiratory health across urban communities during childhood

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A B S T R A C T

Spatial modelling techniques incorporating the social and physical structures of urban environments, previously establish a 'triple jeopardy' of social, respiratory health and environmental inequalities as operating within the multicultural UK City of Leicester (Jephcote & Chen, 2012). Expanding upon our initial findings, we aim to explore whether spatial relationships exist between relatively minor and severe respiratory conditions, and if so, then to what extent socio-environmental mechanisms play in the decline of children's respiratory health. Pearson's Correlation tests identified a high global level of correlation between children's acute upper and lower respiratory tract infections (URTI, LRTI), with Local Moran's *I* spatial autocorrelation tests identifying elevated hospitalisation rates across inner-city locales ($p < 0.05$). Optimally weighted Geographically Weighted Regression models exploring the spatial distribution of children's URTI and LRTI respiratory hospitalisation incidents, expressed the extent to which individual socio-environmental mechanisms impeded health. Bivariate correlation statistics identified significant spatial trends between modelled URTI and LRTI admissions, with deprivation and TPM_{10} emissions detrimentally influencing respiratory health across inner-city communities ($p < 0.05$). In contrast, lifestyle choices such as those seen by Indian residents, appeared to mitigate the onset of such conditions. Our findings suggest that exposure to detrimental socio-environmental factors may initiate URTI episodes, with prolonging recovery times likely occurring from sustained exposures. If a sufficient level of recovery is not reached in time for the cold season, then the child may become host to a viral infection exacerbating previous respiratory complaints. The findings of this investigation appear to confirm the existence of a link between certain socio-environmental influences and cases of 'Catarrhal Child Syndrome'.

Introduction

Over a period of 24-h the average person would be expected to process between 10,000–20,000 L of air (Seaton, Seaton, & Leitch, 1991), which inevitably leaves the host exposed to a plethora of pathogenic microorganisms and detrimental environmental agents. Within adults a combination of anatomical barriers, mechanical mechanisms and established immunoregulatory elements competently prevent the passage and cleanse the respiratory tract of foreign material. In contrast, a child's immune system and lungs are often undeveloped when exposure begins, with full functionality occurring beyond 6 years of age, thus raising the possibility of different responses to those seen in adults (Schwartz, 2004).

Road-transport accounts for a substantial proportion of the air quality objective pollutants experienced within the Post-industrial cityscape, attributed to the movement of labour forces and physical merchandise often within close proximity to residential districts. Traditionally, investigations have quantified the temporal health effects of such pollutants (Atkinson et al., 2003; Dominici, McDermott, Daniels, Zeger, & Samet, 2003), yet the confined nature of European intra-urban environments often determine spatial variations in traffic pollutant levels, which tend to be associated with a plethora of social disparities. The current burden of anthropogenic particulate matter air pollution across the UK is thought to contribute to approximately 29,000 deaths, with an associated total population loss of 340,000 life-years (COMEAP, 2010). Across England substantial demographic disparities are reported in relation to PM_{10} exposure, with 20.3% of the most deprived decile residing within locations experiencing the highest 10% of PM_{10} concentrations, compared to only 2.0% of the country's

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most affluent decile experiencing such burdens (DEFRA, 2006). Furthermore, the relationship between deprivation and exposure would appear most prolific across the 0–14y age group, with population-weighted PM_{10} exposures per child of 29.1 μg/m^3 and 22.8 μg/m^3 experience by England's most deprived and affluent demographics respectively (DEFRA, 2006).

In our previous study (Jephcote & Chen, 2012), we explored the influence of several socio-environmental factors on the complete respiratory burden experienced by children, applying spatial modelling techniques to incorporate the social and physical structures present across an urban environment. The findings indicated significant global relationships to exist between children's hospitalisation rates, social–economic-status, ethnic minorities, and PM_{10} road-transport emissions within Leicester. 'Local Indicators of Spatial Association' (LISA) and Geographically Weighted Regression (GWR) models identified important localised variations within the dataset, specifically relating to a double-burden of residentially experienced road-transport emissions and deprivation effecting inner city children's respiratory health. Prior to this, 'Environmental Justice' studies had rarely tackled the adverse health implications of exposures from mobile sources (Chakraborty, 2009), or had applied statistical techniques appropriate for spatial health datasets (Gilbert & Chakraborty, 2011).

Nevertheless the description of geographic phenomenon, often involves a somewhat naive and subjective selection of weighting structures, potentially constructing models which are unable to capture the underlying spatial interactions in an appropriate form. "The problem is that, unlike the simple notion of a time series lag, the spatial lag is a very fluid and complex entity open to multiple definitions within a single study" (Arbia & Fingleton, 2008). Yet, LeSage and Pace's (2010) investigations found the sensitivity of estimates and inferences over a moderate range of spatial weighting structures to be negligible, dispelling such universally held beliefs. For a generated dataset of 1000 observations, levels of correlation between first order row-stochastic weighting schemes ranged from 0.37 to 0.72, yet effects estimates continued to exhibit high levels of correlation (0.92–0.96), across schemes containing 5–30 nearest neighbours (LeSage & Pace, 2010). In conclusion, LeSage and Pace (2010) dismiss the necessity of fine-tuning spatial weight scheme, placing greater emphasis on a well-specified spatial model.

Several statistical procedures have been adapted and developed specifically to assist with the specification of spatial parameters present within GWR models exploring demographic influences. Studies using a fixed distance-decay weighting structure, have previously compared models across several preselected distances (Mennis & Jordan, 2005), or calculated the optimum bandwidth through minimising Cross-Validation (CV) and Akaike Information Criterion (AIC) scores (Longley & Tobon, 2004). In the Mennis and Jordan (2005) study, model specification appears to be lacking, with locally modelled outputs deemed of significance only by their local R^2 values, a feature commonplace in earlier GWR studies when the technique was deemed more of an exploratory technique used solely to explore the presence of spatial nonstationarity. In contrast Longley and Tobon (2004) validate the overall model performance through checking the residuals to observe whether spatial structures remain, and by conducting Fotheringham, Brunsdon, and Charlton's (2002) *F*-test to compare OLS and GWR model performances.

Distance-decay weighting structures with adaptive bandwidths are more appropriate for demographic datasets, which typically record community details across spaces of irregular size and shape. The benefit of an adaptive bandwidth is that a specific number of observations are maintained within each local model through a kernel optimised for each locality. However, the important question of how many neighbours should be included within each local model still persists. The validation of model choice for GWR models with adaptive bandwidths has previously consisted of comparing OLS and GWR models through AIC scores (Ali & Olfert, 2007; Gilbert & Chakraborty, 2011), and or Fotheringham et al.'s (2002) *F*-test (Ali & Olfert, 2007; Jephcote & Chen, 2012), thus considering the goodness-of-fit in relation to model complexity. Other validation measures have included, checking for spatial artefacts within the residuals (Ali & Olfert, 2007), the inspection of local significance values (Gilbert & Chakraborty, 2011; Jephcote & Chen, 2012) and CV with dependent variables from another time period (Jephcote & Chen, 2012).

It is intended that this research paper will expand upon our initial findings detailing the disparities in children's respiratory health (Jephcote & Chen, 2012), through exploring the extent to which socio-environmental influences influence the development of specific respiratory conditions. Elsewhere, it has been recently been demonstrated that spatial analysis can extend the investigation of diseases with environmental influences (Ayres-Sampaio et al., 2014; Delamater, Finley, & Banerjee, 2012). This paper seeks to add to this research area by exploring the spatial component of potentially more complex relationships. Specifically we consider whether a spatial relationship exists between relatively minor and relatively severe respiratory conditions, and if so, then to what extent do socio-environmental mechanisms play in the decline of children's respiratory health within Leicester. Through answering such questions, we also intend to lay out the foundations for selecting GWR models with the most appropriate spatial structures, through combining several available statistical techniques.

Materials & methods

Study setting

Leicester is a city located in the East Midlands of England which houses some 280,000 inhabitants spread across an area of 73.32 km^2 (Fig. 1); it is regarded as the prototypical British multicultural city. Population demographics from the 2001 UK Census identify 47.09% of children aged 0–15 years to be of ethnic minority, of which 63.71% are identified to be of Indian ethnicity (ONS, 2003). Leicester is also considered a relatively deprived city, ranked as the 31st poorest out of 354 Local Authorities in England under the 2007 Indices of Multiple Deprivation (ONS, 2008a).

Dependent variables

A geocoded respiratory subset of NHS hospital admissions (ICD-10: J00-99) for children aged 0–15 years residing within Leicester Unitary Authority's (UA) 187 Lower Level Super Output Areas (LSOA's) from 2000 to 2009, was obtained through the Leicester City Primary Care Trust (PCT). Across this 10-year period, 24,556 children's respiratory related hospital admissions were recorded, with patient symptoms classified in accordance to ICD-10 protocols (Appendix A).

Respiratory subset admission counts were weighted against the number of persons aged 0–15 years residing within each census area LSOA, in order to obtain a 1-year standardised hospital admission rate for each subset.

Independent variables

Road-transport emissions

Residential exposure to particulate matter up to 10 μm in diameter generated by road-transport (TPM_{10}) was derived