REMOVING THE EFFECTS OF SOCIOECONOMIC STATUS ON THE GEOGRAPHIC DISTRIBUTION OF ASTHMA EVENTS
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ABSTRACT

BACKGROUND: Recent research in Perth, Western Australia has found that the risk of emergency department presentation for asthma is higher among children who live closer to major urban centres such as Perth and Fremantle. However, an increase in socio-economic status is also strongly associated with proximity to these areas. The influence of socio-economic status is yet to be comprehensively assessed as a spatial confounder.

METHOD: The study population consisted of 1809 children aged between 0 and 19, resident in a south-west metropolitan area of Perth, Western Australia, who had presented at an emergency department between 2002 and 2006. A matched case-control study was used to select 603 asthma cases and 1206 gastroenteritis and upper limb injury controls. Specially designed maps were created to assess the influence of socio-economic status as a confounder. A map displaying changes in the risk of emergency department presentation for asthma (i.e. a risk field) was compared to a map showing changes in socio-economic status in the study area (i.e. a vector field for socio-economic status).

RESULTS: The geographic variability in risk of asthma presentation is not fully explained by socio-economic disadvantage. Higher socio-economic status subjects were more likely to have resided in the northern and eastern parts of the study area. For a 1km increment in residential address in the easterly and northerly directions the socio-economic status index increased by 3.38 (95%CI 2.59 - 4.16 ) and 3.12 (95%CI 1.87 -4.38). These changes represent 2.5% and 2.3% of the interquartile range of the socio-economic status index respectively. However, the vector field for socio-economic status was not consistent with the risk field across the entire study area.

CONCLUSION: The inconsistency between the two maps indicated that the observation of increased risk with residential proximity to the major urban centres can not be fully explained by spatial gradients in socio-economic status. The geographic variation in the risk is consistent with
the direction of predominant traffic flow and warrants further research and formal testing of this new hypothesis. Finally, the risk field approach was effective in demonstrating these results.
BACKGROUND

A recent exploratory spatial study conducted in Perth, Western Australia found that the risk of hospital emergency department presentations for asthma increases with residential proximity to the two major urban centres, Perth and Fremantle (Pereira, De Vos et al. 2009). Furthermore, under higher spatial resolution the risk aligns with motor vehicle routes during the peak morning traffic period. These findings suggest that characteristics of major urban centres, perhaps associated with traffic flow, exacerbate respiratory health conditions. Most importantly, these findings identify triggers for asthma that are preventable and may therefore provide impetus for policy change in relation to emissions standards and urban planning. However, an increase in socio-economic status is also strongly associated with proximity to these areas, yet its influence is yet to be comprehensively assessed as a confounder or effect modifier in a spatial context.

Past research has demonstrated associations between socio-economic disadvantage and asthma-related health endpoints (Mielck, Reitmeir et al. 1996; Kolbe, Vamos et al. 1997; Basagana, Sunyer et al. 2004; Neidell 2004; Blanc, Yen et al. 2006). Moreover, geographical gradients in socio-economic status are common across developed countries, but may differ in direction. For instance, subjects of lower socio-economic status are more likely to live inner city than suburbs within the United States, but in Europe living closer to the city is associated with higher SES (Slama, Darrow et al. 2008).

Briefly, the Perth study encompassed 613 census collection districts (CDs) in the south-western region of the Perth metropolitan area containing a total population of 269,734 (2006 Census of Population and Housing). The cases (n=603) were all individuals aged 0-19 years with residential addresses in the study area, who presented at the emergency department (ED) of any Perth metropolitan hospital in 2002-2006, with a principal diagnosis of asthma (J45) or status asthmaticus (J46). For each case, two controls were selected, corresponding to each control disease. Controls (n=1206) were similarly defined, except that for the principal diagnosis, which was either gastroenteritis (A00-A09) or upper limb injury (S40-S69).

An outcome of the Perth study was the construction of a risk field, defined as a map consisting of a set of arrows anchored at residential locations that point in the direction of
maximal risk of an asthma event based on the geographic distribution of the 50 neighbouring cases and their matched controls. The case and control locations were reproduced in Figure 1, and the risk field in Figure 2 below. Unlike previous studies, relative lower levels of socio-economic disadvantage were observed to elevate the risk of emergency department presentation for asthma in the Perth study.

“Insert Figure 1 here”

“Insert Figure 2 here”

A choropleth map of SEIFA quintiles is produced in Figure 3. The map shows the contrast in socio-economic status between the CDs of the study area that are closer to the Swan/Canning rivers and the other CDs within the study area.

“Insert Figure 3 here”

The aim of this study was to assess the influence of gradients in socio-economic status as a spatial confounder on the results of the Perth asthma study. We constructed a geographical map for spatial gradients in socio-economic status using a vector approach. This provided a visual comparison with the results shown in Figure 2. In this way we were able to visually assess whether gradients in socio-economic status were removed by adjustment, or whether the systematic pattern of risk shown in Figure 2 was due to residual confounding. In this study, the vector approach is defined by a map of vectors (or arrows). Each vector is anchored at the residential address of a reference case. The direction of each vector is obtained by maximising the change in socio-economic status, based on the residential locations of the 50 neighbouring cases and their matched controls.
METHOD

Latitude and longitude coordinates of the residential addresses for cases and controls were projected using a transverse Mercator projection into the Geocentric Datum of Australia 1994 Map Grid of Australia Zone 50 using ArcGIS 9.2 (ESRI 2008). The Socio-economic Index for Areas (SEIFA) disadvantage score was obtained for each census collection district and assigned to the subjects based on residential location, as individual-level socio-economic status was unavailable (Australian Bureau of Statistics 2006). This score is standardised against a mean of 1000 with a standard deviation of 100 (Australian Bureau of Statistics 2006). A lower score represents relative disadvantage. A multiple regression model for the SEIFA response variable was applied using the projected easting and northing coordinates as independent variables. The regression coefficients informed the direction of maximal increase in the SEIFA index. The model was calculated using the GLM procedure of SAS v9.1 (SAS Institute Inc. 2003). The model was applied for each reference case using 50 nearest neighbouring cases and their matched controls, for comparability with the risk field map corresponding to asthma emergency department presentations. That is, a total of 603 regression models were applied to each reference case to calculate a vector anchored at the residential location of the case, pointing in the direction of maximal increase in SEIFA. Initially, a choropleth map of SEIFA quintiles was produced to provide an indication of spatial socio-economic gradients.

RESULTS

Across the study area as a whole, a 1km movement in the easterly and northerly directions resulted in a statistically significant increase in the SEIFA score; 3.38 (95%CI 2.59 - 4.16 ) and 3.12 (95%CI 1.87 -4.38). These changes represent 2.5% and 2.3% of the interquartile range of SEIFA, respectively. However, the choropleth map (Figure 3) confirms further systematic spatial variation in SEIFA at scales providing more detail. A vector field for spatial gradients in SEIFA using the subjects from the Perth study is shown in Figure 4. This map provides an indication of the geographic direction of maximal increase in SEIFA based on the residential locations of the same subjects as those used in the construction of the risk field. Comparison of the two vector
fields highlights inconsistencies in multiple sub-regions of the study area. Based on the residential locations of cases and controls, in the west of the study area SEIFA tends to increase away from Fremantle in a north-easterly direction compared with the risk field which shows that risk of asthma emergency department presentation increases towards Fremantle. In the northern section of the study area the directions of vectors for increase in SEIFA are inconsistent, while the risk field in this section is consistently directed toward Perth. Moreover, the vector field for SEIFA is directed towards the Swan and Canning rivers, which was also observed in the choropleth map. However, the risk vectors immediately north of the Canning river consistently deviate away in the direction of Perth. Therefore, the geographic distribution in the risk of asthma presentation increases toward the major urban centres, beyond what can be fully explained by spatial gradients in socio-economic status.

“Insert Figure 4 here”

A kernel smoothed map of population density with residential locations for cases and controls is produced in Figure 5. The residential locations for the controls did not adhere to the population distribution, unlike those for the cases.

“Insert Figure 5 here”

DISCUSSION

The aim of this study was to assess the influence of gradients in socio-economic status as a spatial confounder on the results of the Perth asthma study, in which risk increased with proximity to the two major urban centres of Perth and Fremantle. By comparing the asthma risk field to the SEIFA vector field we were able to determine that the geographic patterns in risk of asthma ED presentation can not be fully explained by spatial gradients in socio-economic status. An associative study between the risk and SEIFA vectors was not conducted as this would test
for the existence of a spatial association between socio-economic status and the risk of asthma ED presentation rather than systematic departure from this relationship, which was achieved by our study. Our approach also enabled us to identify sub-sections of the study area in which such a departure existed.

Despite these advantages, two related methodological questions must be considered: whether the geographic pattern of risk depends on differential accessibility to an emergency department with respect to residential location; and whether the control distribution reflects the background population at risk. Case and control populations were obtained from presentations across all public hospital EDs in the Perth metropolitan area. It is plausible that potential cases and controls presented at after-hours medical centres or private hospital EDs for which data was not available. However, in order to induce the observed effect, subjects living in the parts of the study area with sparse controls were more likely present with gastroenteritis or an upper limb injury at nearby private health care providers but present with asthmatic symptoms at a public hospital ED. Furthermore, the sections of the study area least populated by controls occurs in the north-eastern part of the study area which are closer in proximity to most of the metropolitan public hospitals. Our results suggest that the geographic pattern of risk does not depend on differential accessibility to a health care provider.

Gastroenteritis and accidental falls have been used as control diseases in other asthma-studies (Lipsett, Hurley et al. 1997; Lin, Munsie et al. 2002; Oyana, Rogerson et al. 2004). We observed that each of the controls, gastroenteritis and upper limb injury, were generally located in the southern and western parts of the study area. Comparison with a kernel smoothed map of population density indicated that the residential locations for these controls did not adhere to the population distribution, unlike those for the cases (Figure 5).

Moreover, residential locations of the controls were not systematically associated with socio-economic disadvantage as indicated by comparison with the geographic SEIFA distribution (Figure 3). Therefore, it is plausible that the association between relative lack of socio-economic disadvantage and elevated risk of asthma ED presentation is due to inherent differences between these populations, beyond those characterised by SEIFA. We conclude that the control
diseases selected may not best represent children in the general population at risk of asthma ED presentation. Nevertheless, both cases and controls were drawn from a hospital-based source and therefore would be expected to be similar in demography. Furthermore, each control disease independently exhibited a similar geographic distribution to that of the case population.

Our result suggest that spatial gradients in socio-economic status as characterised by SEIFA explain some but not all of the geographic variation in risk and do not explain the systematic increase in risk toward the major urban centres. This may be due to the differences between area-level SEIFA and individual-level socio-economic disadvantage or the modifiable areal unit problem (MAUP). The MUAP states that inference is dependent upon scale. This is unlikely in the Perth study as the effect of spatial scale was assessed by sensitivity analysis, which showed little difference in magnitude and direction of the risk vectors for different values of the smoothing parameter.

The health of the population in relation to anthropogenic environmental influences such as traffic emissions and industrial pollutants should be a significant factor when assessing the state of Australian cities. Exploratory geographical approaches such as traditional choropleth maps and more recent risk vectors are hypothesis generators, providing an indication of putative hazards that can be identified by observation of geographic variability. However, the health status of an individual is also impacted upon by socio-economic influences, which also exhibit spatial gradients. Confounding is possible when there are similarities between the spatial gradient in risk and that of socio-economic disadvantage. In this study, we found that spatial gradients in socio-economic disadvantage do not explain the systematic pattern of risk of asthma ED presentation in Perth, which is depicted by an increase in risk towards the major urban centres. Further investigation is required to identify the precise set of causes of this pattern of risk in Perth, and to identify whether this pattern is also observable in other Australian cities.

CONCLUSION

The systematic geographic pattern in the risk of asthma ED presentation is not due to spatial gradients in area-level socio-economic deprivation. The geographic variation in the risk is
consistent with the direction of predominant traffic flow, location of traffic congestion, and putative hazards present in major urban centres. The risk field approach was effective in generating these new hypotheses and assessing the influence of spatial gradients in socio-economic status.

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References

Figure 1: Study area in the south-west metropolitan area of Perth, Western Australia. Case (red) and control (yellow) locations have been jittered.

Software Source: (Aanensen ; Google)
Figure 2: Risk field for ED presentation for asthma using 50 neighbouring cases and their matched controls, adjusted for SEIFA.

Source: (Pereira, De Vos et al. 2009)
Figure 3: Choropleth map of SEIFA quintiles where low scores indicate relative disadvantage
Figure 4: Vector field for SEIFA using 50 neighbouring cases and their matched controls. Arrows point in the direction of highest SEIFA.
Figure 5: Residential locations of subjects with kernel smoothed population density

5a. Controls

5b. Cases