RESEARCH REPORT

Ecological association between suicide rates and indices of deprivation in the north west region of England: the importance of the size of the administrative unit

Mohsen Rezaeian, Graham Dunn, Selwyn St Leger, Louis Appleby

J Epidemiol Community Health 2006;**60**:956–961. doi: 10.1136/jech.2005.043109

See end of article for authors' affiliations

Correspondence to: M Rezaeian, Department of Social Medicine, Rafsanjan Medical School, Rafsanjan 7719617996, Iran; moeygmr2@yahoo.co.uk

Accepted 7 March 2006

Background and objective: Most published research on the ecological relationship between suicide rates and indices of deprivation uses only one level of population aggregation—for example, by local authorities. These ecological associations have been studied at both the local authority and the electoral ward level.

Methods: Data on all deaths for which suicide or an open verdict was returned between 1996 and 1998 in the North West Government Office Region (NWGOR) of England (2336 cases) were the subject of this study. These data were provided by the National Confidential Inquiry into Suicide and Homicide by People with Mental Illness. The income and employment indices of deprivation and the population counts were provided by the Department of the Environment, Transport and the Regions, and the Office for National Statistics, respectively.

Results: Modelling data at the local authority and ward levels in the NWGOR showed that although at the local authorities level there are no significant associations between suicide rates and two indices, at the ward level there are significant associations. The direction of these associations is such that with an increase in the quartile ranks of each index (ie, with improving the situation of a ward in terms of that index), the rate of suicide decreases.

Conclusion: A lack of effect was found once we move from ward to local authority level. This may happen because of the non-homogeneous nature of the local authorities in terms of their income and employment indices. In this sense, wards are more homogeneous. This means that in examining ecological risk factors, a balance was found between large areas (diluted effects but greater power) and small areas.

Most published research on the ecological associations between suicide rates and indices of deprivation or fragmentation has used only one level of population aggregation—for example, by local authorities. Moreover, these studies did not directly deal with the spatial dependency between suicide rates in the neighbouring areas.^{1–8}

Detecting spatial dependency, which is usually accomplished by the use of spatial autocorrelation statistics,⁹ would help researchers to justify their selected regression models in an ecological analysis. In fact, these statistics compare neighbouring area values (suicide rates) to assess the level of large-scale clustering (the overall clustering) tendency of disease incidence in a study region.¹⁰ Whenever a large number of neighbouring areas have either relatively high or small values, large-scale clustering may be detected.¹¹ If this happens, then a richer statistical model with spatial autocorrelation should be applied to analyse the data.¹² This important issue has been explored in a recent study in the area of suicide studies.¹³

Given that the geographical analyses crucially depend on scale,¹⁴ we have studied the ecological associations between suicide rates and indices of deprivation at both local authority and electoral ward level within the North West Government Office Region (NWGOR) of England. Furthermore, as modelling ecological regression without taking into account the spatial dependency of the variables may confound the relationship owing to location,¹⁵ in our analyses we have considered not only the results of spatial autocorrelation statistics of suicide rates within local authorities but also the nested structure of neighbouring wards within the local authorities.

METHODS

Data on all deaths for which suicide or an open verdict was returned between 1996 and 1998 in the NWGOR were the subject of this study. These data were provided by the National Confidential Inquiry into Suicide and Homicide by People with Mental Illness (NCI). Suicide is defined by the NCI as¹⁶

Deaths which at coroner's inquest received a verdict of suicide or an open verdict, excluding open verdicts in which suicide was clearly not considered. Therefore, it includes suicides and probable suicides but excludes death receiving any other verdict such as misadventure.

On the basis of this definition, suicide data in this study correspond to the International Classification of Diseases ninth revision codes E950–E959 (suicides) and E980–E989 (open verdicts). However, data exclude all E988.8 codes, as these are consideration to be victims of homicide.¹⁷

There were 1514 (64.8%) cases of suicide and 822 (35.2%) open verdicts in the NCI database, adding up to 2336 cases overall whose last address was in the NWGOR. Of these 2336 cases, it was possible to ascertain the postcodes of the last place of residence for 2283 (97.7%) and the partial postcodes for 53 (2.3%). In the next step, it was possible to find the relevant ward, which contains nearly 5000 people,¹⁸ and subsequently the relevant local authority, which varies

Abbreviations: NCI, National Confidential Inquiry; NWGOR, North West Government Office Region

Table 1 Description of the cases and 1998 estimation of population at the local authority level in the North West Government Office Region

	Minimum	Maximum	Mean (SD)
Male suicide			
10–29 years	0	45	10.26 (8.33)
30–49 years	3	83	19.02 (15.66)
≥50 years	2	32	11.72 (7.21)
Female suicide			
10–29 years	0	12	2.42 (2.51)
30–49 years	0	25	5.14 (5.51)
≥50 years	0	17	5.70 (4.06)
Male population			
10–29 years	6173	69777	21487.21 (14361.87)
30–49 years	7157	66452	23068.81 (13860.27)
≥50 years	8617	60225	23517.95 (12827.32)
Female population			
10–29 years	5552	66951	20338.40 (13719.46)
30–49 years	6724	66954	22593.77 (13804.47)
≥50 years	9856	75293	28527.86 (16174.51)

The minimum and maximum observed number of suicides and the estimation of population sizes for six groups categorised by age and sex.

considerably in its size and population,¹⁹ for each case. The cases were scattered throughout 725 wards within 43 local authorities. We will not dwell on the quality of the NCI data or on the technical details of finding the postcodes and wider geographical areas here but refer the reader to the NCI website and the paper by Rezaeian *et al.*²⁰

To estimate local authority and ward suicide rates, we need to know the numbers of people at risk. At the local authority level, data on the 1998 total population and its breakdown into different age groups and sexes were obtained from the Office for National Statistics and used in the calculations of suicide rates. However, as the local authority is the lowest area level for which the Office for National Statistics currently produces population estimates for different age groups and sexes,²¹ the 1998 population estimated for each age group and sex at ward level was obtained in the following way. The population count from the 1991 census for the same age group and sex was multiplied by the estimated 1998 total population in each ward, obtained from Office for National Statistics, and then divided by the 1991 total population count of the same ward, again obtained from 1991 census. This is a simple and easy method to implement. However, there is one problem, which is the assumption that the changes in population in the different age groups and sexes during the time span of the estimation are the same. This assumption cannot be justified for all wards and, therefore, the result of this part of the analyses should be considered with caution.

The indices of deprivation were provided by the Department of the Environment, Transport and the

Regions.²² These indices include several measures to show the extent of different aspects of deprivation at both local authority and ward level. We carried out analyses for all indices of deprivation. However, as almost all indices were highly correlated and showed relatively similar results, for the sake of brevity we report only the results of the first two of these indices. These are the Income Scale Score, which indicates the number of people who are income deprived, and the Employment Scale Score, which indicates the number of people who are unemployed.

For each measure, each local authority and ward is given a rank and score. We examined the deprivation indices in their rank formats. The reason for this decision was the existence of comparable ranks for each of these indices. Furthermore, the large number of ecological units of analyses (ie, 43 local authorities and 725 wards) also justified this decision.

To select the most appropriate model (at the local authority level), we have first tested for spatial dependency between the suicide rates of neighbouring areas using Moran's I and Geary's c statistics.^{23–24} These statistics are the most important ones for detecting spatial dependency for morbidity and mortality.⁹ The results indicated that there is no spatial dependency between adjacent regions and therefore the two following statistical models have been selected. The first model is the log-linear Poisson regression model,²⁵ which is usually applied to model the random occurrence of rare discrete events, of which suicide is a good example.²⁶ In this model an offset (ie, an explanatory variable with known regression coefficient²⁷) has been used, which is the logarithm of the estimate of the population size in each local

Table 2 Incident rate ratios (and 95% CI) from the Poisson or negative binomial models of suicide in males resident in the North West Government Office Region at the local authority level

Explanatory variables	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Linear model
Males, 10–29 years					
Income scale*	1	0.95 (0.70 to 1.28)	0.78 (0.49 to 1.24)	0.99 (0.55 to 1.76)	0.95 (0.81 to 1.10)
Employment scale*	1	1.06 (0.80 to 1.42)	0.64 (0.37 to 1.10)	1.05 (0.54 to 2.08)	0.95 (0.80 to 1.12)
Males, 30–49 years					
Income scale*	1	0.90 (0.73 to 1.13)	0.74 (0.52 to 1.05)	0.89 (0.58 to 1.40)	0.92 (0.82 to 1.03)
Employment scale*	1	0.93 (0.75 to 1.16)	0.70 (0.48 to 1.04)	1.07 (0.66 to 1.73)	0.94 (0.83 to 1.06)
Males, ≥50 years					
Income scale*	1	1.15 (0.94 to 1.41)	0.94 (0.67 to 1.33)	1.10 (0.72 to 1.65)	1.03 (0.93 to 1.14)
Employment scale*	1	1.09 (0.88 to 1.33)	0.99 (0.70 to 1.42)	1.04 (0.63 to 1.73)	1.02 (0.91 to 1.15)

*The result of the likelihood ratio test justifies dropping these explanatory variables from the model.

Table 3 Incident rate ratios (and 95% CI) from the Poisson or negative binomial models of suicide in females resident in the North West Government Office Region at the local authority level

Explanatory variable	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Linear model
Females, 10–29 years					
Income scale*	1	1.14 (0.72 to 1.80)	1.21 (0.60 to 2.43)	0.29 (0.04 to 2.08)	0.96 (0.75 to 1.24)
Employment scale*	1	1.23 (0.79 to 1.93)	1.15 (0.53 to 2.51)	0.45 (0.06 to 3.28)	1.03 (0.78 to 1.34)
Females, 30–49 years					
Income scale*	1	0.70 (0.47 to 1.04)	0.54 (0.27 to 1.07)	0.43 (0.15 to 1.21)	0.73 (0.58 to 0.92)
Employment scale	1	0.66 (0.45 to 0.99)	0.51 (0.24 to 1.09)	0.33 (0.08 to 1.40)	0.69 (0.53 to 0.89)
Females ≥50 years					
Income scale*	1	1.19 (0.89 to 1.58)	0.79 (0.46 to 1.35)	0.84 (0.43 to 1.65)	0.97 (0.83 to 1.13)
Employment scale*	1	1.13 (0.84 to 1.50)	0.98 (0.58 to 1.63)	0.81 (0.36 to 1.83)	1.00 (0.84 to 1.17)

*The result of the likelihood ratio test justifies dropping these explanatory variables from the model.

authority. In effect, by the inclusion of this offset, it has been possible to model a rate rather than a count. The second model used was a negative binomial regression model,²⁸ which was used if the log-linear Poisson regression model was inadequate owing to “extra-Poisson” variation or over-dispersion.²⁹

Similar models and procedures have also been applied for data at ward level. However, at this level, to control for the nested structure of the data (ie, neighbouring wards within local authorities) by including a cluster term in the model, we have fitted a log-linear hierarchical (nested) Poisson or negative binomial model. This cluster indicator specifies the local authority to which each ward belongs.

Using these models enables us to investigate the effects of deprivation indices on the suicide rates of the different age groups and sexes and estimate their 95% confidence intervals (CIs). Here, we have chosen six groups categorised by age and sex (ie, 10–29, 30–49 and ≥50 years, for males and females separately). Data were analysed using Stata V.6.0.³⁰

RESULTS

Results for the local authority level

Relative to the mean, the value of the standard deviation (SD) for the observed number of suicides and the estimation of population sizes for people aged ≥10 years in the six groups categorised by sex and age at the local authority level is high. For some variables the value of the standard deviation is near to, or even greater than, the value of the mean, indicating that these variables are highly positively skewed (table 1).

Table 4 Description of the cases and 1998 estimation of population at ward level in the North West Government Office Region

	Minimum	Maximum	Mean (SD)
Male suicide			
10–29 years	0	4	0.42 (0.72)
30–49 years	0	8	0.80 (1.14)
>50 years	0	5	0.49 (0.79)
Female suicide			
10–29 years	0	2	0.10 (0.30)
30–49 years	0	4	0.21 (0.50)
≥50 years	0	3	0.24 (0.50)
Male population			
10–29 years	90	3338	950.22 (621.92)
30–49 years	93	3438	952.22 (637.74)
≥50 years	107	2670	911.84 (571.70)
Female population			
10–29 years	109	2769	920.77 (583.05)
30–49 years	136	2927	965.44 (587.30)
≥50 years	138	4341	1220.89 (777.51)

Furthermore, the correlation between the two deprivation indices in their categorised rank formats shows that there are high positive correlations between them (0.997). The test for Spearman's correlation coefficient shows that this correlation is significant ($p=0.001$). These findings indicate that entering these two highly correlated explanatory variables with each other in regression analysis would make the estimation of easily interpretable regression coefficients impossible. To avoid this problem, it was decided to model the rate of suicide taking into account each explanatory deprivation index separately.

In all age and sex groups (tables 2 and 3), except females 30–49 years old, none of the explanatory variables shows any association with the rate of suicide.

Results for the ward level

As in the case for local authorities, from the highly positively skewed nature of the data (table 4) and the high correlation existing between the two deprivation indices, we modelled the rate of suicide taking into account each explanatory deprivation index separately.

In males 10–29 years old (table 5), two variables show a strong association with the rate of suicide. The incident rate ratios of suicide across the quartiles of these two explanatory variables show stepwise decreases. The linear model also confirms that with increasing 1 unit in the quartile rank of these variables (ie, with improving the situations of local authorities), the rate of suicide decreases by between 19% and 23% (95% CI 11% to 33%). The results for males 30–49 years old (table 5) are very similar to those for males 10–29 years old. From the linear models it can be seen that the rate of suicide decreases by between 17% and 19% (95% CI 9% to 36%) with each increase of 1 unit in the quartile rank of these indices of deprivation. In males ≥50 years old (table 5), these two variables again show a degree of association with the rate of suicide. The linear model also confirms that with increasing 1 unit in the quartile rank of these variables the rate of suicide decreases by between 9% and 11% (95% CI 0 to 17%).

In females 10–29 years old (table 6), these two variables show a strong association with the rate of suicide. The linear model confirms that with an increase of 1 unit in the quartile rank of these variables the rate of suicide decreases by between 18% and 22% (95% CI 1% to 36%). In females 30–49 years old (table 6), these two variables again show a strong association with the rate of suicide. The linear model confirms that with an increase of 1 unit in the quartile rank of these variables the rate of suicide decreases by between 34% and 36% (95% CI 26% to 46%). In females ≥50 years old (table 6), none of the variables show any significant association with the rate of suicide; however, they show a

Table 5 Incident rate ratios (and 95% CI) from the Poisson or negative binomial models of suicide in males resident in the North West Government Office Region at ward level

Explanatory variable	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Linear model
Males, 10–29 years					
Income					
Before clustering	1	0.77 (0.62 to 0.97)	0.56 (0.43 to 0.73)	0.48 (0.33 to 0.69)	0.77 (0.69 to 0.85)
After clustering	1	0.77 (0.58 to 1.02)	0.56 (0.41 to 0.75)	0.48 (0.34 to 0.69)	0.77 (0.69 to 0.85)
Employment					
Before clustering	1	0.80 (0.64 to 1.00)	0.59 (0.45 to 0.77)	0.58 (0.42 to 0.81)	0.81 (0.73 to 0.89)
After clustering	1	0.80 (0.60 to 1.06)	0.59 (0.45 to 0.76)	0.58 (0.41 to 0.82)	0.81 (0.72 to 0.89)
Males, 30–49 years					
Income					
Before clustering	1	0.79 (0.65 to 0.94)	0.69 (0.56 to 0.85)	0.49 (0.37 to 0.66)	0.81 (0.75 to 0.87)
After clustering	1	0.79 (0.64 to 0.97)	0.69 (0.56 to 0.86)	0.49 (0.34 to 0.67)	0.81 (0.74 to 0.88)
Employment					
Before clustering	1	0.81 (0.67 to 0.97)	0.63 (0.51 to 0.78)	0.62 (0.48 to 0.80)	0.83 (0.77 to 0.89)
After clustering	1	0.81 (0.66 to 0.99)	0.63 (0.50 to 0.79)	0.62 (0.46 to 0.84)	0.83 (0.75 to 0.91)
Males ≥50 years					
Income					
Before clustering	1	0.77 (0.60 to 0.98)	0.75 (0.58 to 0.96)	0.71 (0.52 to 0.96)	0.89 (0.81 to 0.97)
After clustering	1	0.77 (0.60 to 0.98)	0.75 (0.58 to 0.97)	0.71 (0.52 to 0.97)	0.89 (0.81 to 0.97)
Employment					
Before clustering	1	0.73 (0.57 to 0.93)	0.71 (0.55 to 0.91)	0.80 (0.61 to 1.07)	0.91 (0.83 to 0.99)
After clustering	1	0.73 (0.57 to 0.92)	0.71 (0.53 to 0.95)	0.80 (0.61 to 1.06)	0.91 (0.83 to 1.00)

non-significant association with the rate of suicide, which follows the other ward-level results.

In all of these groups, the introduction of clustering terms into the model does not seem to have a big influence on the 95% CIs of suicide rates. It seems that for most of the time, it makes this CI wider. However, there are situations in which this term makes the 95% CI narrower, and there are also a few situations in which the clustering has no influence on the CI at all.

DISCUSSION

In the area of spatial data analysis, there are some situations in which we might search for a relationship between a measure of morbidity or mortality (suicide) and social or environmental covariates (socioeconomic indices of deprivation).³¹ This kind of study, usually termed “ecological correlation study”, aims to analyse the association between a set of variables defined on aggregated groups of people at the area level.³²

The reason for focusing on the comparison of groups rather than individuals, is that individual-level data are usually missing on the joint distribution of at least two or more variables within each group.³³ In any ecological study, there are, however, important issues that need to be taken into account to reach a firmer conclusion. One of these issues is the level of aggregation and another is the spatial dependency between outcome rates.

Regarding the level of aggregation, if the regions are large, there is a greater possibility that associations measured at the aggregate level will differ from the same association measured at the individual level. This is sometimes referred to as the ecological fallacy,³⁴ cross level or ecological bias.³⁵ Any associations apparent at the area level might not be relevant at the individual level. Although the possibility of bias does not mean that it is actually present,³⁶ if the target level of inference is the area rather than the individual, the possibility of an ecological fallacy should always be considered to be a potential source bias in ecological studies.³⁷

Table 6 Incident rate ratios (and the 95% CI) from the Poisson or negative binomial models of suicide in females resident in the North West Government Office Region at ward level

Explanatory variable	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Linear model
Females, 10–29 years					
Income				a	
Before clustering	1	0.75 (0.47 to 1.19)	0.49 (0.29 to 0.86)	0.57 (0.29 to 1.08)	0.78 (0.64 to 0.95)
After clustering	1	0.75 (0.47 to 1.19)	0.49 (0.30 to 0.82)	0.57 (0.32 to 1.01)	0.78 (0.65 to 0.93)
Employment					
Before clustering	1	0.52 (0.31 to 0.88)	0.71 (0.43 to 1.15)	0.52 (0.27 to 0.99)	0.82 (0.68 to 0.99)
After clustering	1	0.52 (0.29 to 0.92)	0.71 (0.48 to 1.04)	0.52 (0.27 to 1.01)	0.82 (0.69 to 0.99)
Females, 30–49 years					
Income					
Before clustering	1	0.59 (0.43 to 0.81)	0.36 (0.24 to 0.53)	0.31 (0.18 to 0.52)	0.64 (0.55 to 0.74)
After clustering	1	0.59 (0.40 to 0.87)	0.36 (0.25 to 0.52)	0.31 (0.17 to 0.57)	0.64 (0.54 to 0.75)
Employment					
Before clustering	1	0.53 (0.38 to 0.74)	0.47 (0.32 to 0.68)	0.28 (0.16 to 0.48)	0.66 (0.57 to 0.76)
After clustering	1	0.53 (0.37 to 0.75)	0.47 (0.32 to 0.69)	0.28 (0.16 to 0.51)	0.66 (0.56 to 0.78)
Females ≥50 years					
Income					
Before clustering	1	1.15 (0.83 to 1.57)	1.06 (0.76 to 1.49)	0.81 (0.52 to 1.26)	0.96 (0.85 to 1.08)
After clustering	1	1.15 (0.93 to 1.41)	1.06 (0.82 to 1.38)	0.81 (0.56 to 1.16)	0.96 (0.88 to 1.04)
Employment					
Before clustering	1	1.35 (0.99 to 1.86)	0.99 (0.70 to 1.41)	0.94 (0.62 to 1.44)	0.97 (0.86 to 1.09)
After clustering	1	1.35 (1.01 to 1.86)	0.99 (0.78 to 1.31)	0.94 (0.69 to 1.27)	0.79 (0.89 to 1.05)

What this paper adds

- Ecological studies conducted for smaller areas—for example, wards rather than local authority boundaries—are probably more informative when there is reasonable supposition that area characteristics are predictive of suicide.

Regarding spatial dependency between outcome rates, it should be emphasised that the failure to take into account this dependency may bias the association between mortality and deprivation, and erroneously suggest a direct relationship between these two factors.³⁸ In the area of suicide research, only a few studies^{13 20 39–41} have directly dealt with the importance of looking at the spatial dependency of the suicide data, or the use of statistical modelling to control for this dependency.

Hence, we found a lack of effect once we move from ward to local authority level. The findings suggest that while at the local authority level, income and employment indices of deprivation could not predict the rate of suicide for any of the age and sex groups, at ward level they could predict rates for all age and sex groups excluding females ≥ 50 years. This may be due to the non-homogeneous nature of the local authorities in terms of their deprivation indices.²² In this sense wards are more homogeneous. However, even at ward level, from the arbitrary nature of the administrative boundaries, there still may be heterogeneity in terms of deprivation. In conclusion, this means that in examining ecological risk factors, there is a balance to be found between large areas (diluted effects but greater power) and small areas.

We have already shown that when all English local authorities are considered, in males (all age groups) and in the middle-aged females, income and employment indices of deprivation predict the rate of suicide.³⁹ Comparison of our previous study with the present one shows two things. Firstly, it may be possible that by considering all local authorities, we reach greater power to detect any associations. Secondly, it is also possible that each region of the country may represent a unique pattern of association between rates of suicide and indices of deprivation which differs from that of the country as whole. This is a topic worthy of future consideration.

Finally, introducing the nested structure of data (ie, wards nested in the local authorities) did not have a very big influence on the 95% CI of suicide rates. This seemed to suggest that there is no strong spatial dependency between rates of suicide in the NWGOR at ward level. This is consistent with the results from the spatial autocorrelation tests and our spatial analyses, which we have reported here for the NWGOR local authorities and elsewhere for all English local authorities,^{20 39} indicating that there is no strong spatial dependency between rates of suicide for English local authorities.

LIMITATIONS

We have shown that the results of ecological (geographical) analyses of suicide can depend crucially on the scale of the geographical units. It is therefore important to take the scale of the analyses into account and if possible to evaluate the sensitivity of any results to change of scale. If relevant geographical data are available, there is also the possibility of applying multilevel modelling⁴² to determine how much of the ecological effect can be explained by variations in the distribution of risk factors at different scales, even at the

Policy implications

- Suicide prevention strategy of each local authority and health service should be in line with the specific socioeconomic and social cohesion characteristics of their own catchment areas, especially for small units such as wards.

individual level.⁴³ The NCI database has no information about an individual's income or employment status and it is not possible for us to adopt such an approach.

In the NCI database, it is also impossible to determine how long a suicidal person was living at his or her last address, or whether he or she had a history of moving between local authorities or wards. It is possible that the person may have moved to that area just before their suicide.⁴⁴ This can introduce an element of uncertainty into the findings, but it is extremely difficult to assess its effect on our results.

Finally, we have studied the ecological association of suicide rates with the highly correlated indices of deprivation. There might be other factors such as the social cohesion characteristics of the area, which may also ecologically be associated with the rates of suicide but were not taken into account in our analyses. Furthermore, it might be possible that people with higher risk of suicide move to deprived areas (ie, social drift due to poor financial and social resources) or these areas may contain more hostels for people who have mental disorders.⁵

PUBLIC HEALTH IMPLICATIONS OF THE RESULTS

Ecological studies are fruitful in terms of health policy and health planning because they may help to identify places where there is most need of healthcare resources or interventions.^{45 46} However, because of ecological fallacy, the overall characteristics of the population of the area to which people belong may not be those of the individuals who commit suicide.⁵ Yet, evidence suggests that the smaller the area the more likely a case will be represented in its overall characteristics.⁴⁷ Therefore, those ecological studies conducted for smaller areas—for example, wards rather than local authority boundaries—are probably more informative in terms of health policy and health planning when there is reasonable supposition that area characteristics are predictive of mental illness and suicide.

In the National Suicide Prevention Strategy for England, the need to deal with the mental health needs of socially excluded and economically deprived groups has been emphasised.⁴⁸ Our findings suggest that the response of each local authority and health service to this broad aim should be in line with the specific socioeconomic and social cohesion characteristics of their own catchment areas, especially for small units such as wards.

ACKNOWLEDGEMENTS

We thank the three anonymous referees for their valuable comments on the earlier draft of this article.

Authors' affiliations

M Rezaeian, G Dunn, Biostatistics Group, Division of Epidemiology and Health Sciences, University of Manchester, Manchester, UK
S St Leger, Evidence Based Population Health Unit, School of Epidemiology and Health Sciences, University of Manchester
L Appleby, Division of Psychiatry, University of Manchester

Competing interests: None declared.

REFERENCES

- 1 Evans J, Middleton N, Gunnell D. Social fragmentation, severe mental illness and suicide. *Soc Psychiatry Psychiatr Epidemiol* 2004;**39**:165–70.
- 2 Middleton N, Gunnell D, Frankel S, et al. Urban–rural differences in suicide trends in young adults: England and Wales, 1981–1998. *Soc Sci Med* 2003;**57**:1183–94.
- 3 Gunnell D, Middleton N, Whitley E, et al. *An investigation into recent temporal trends and geographical patterns of suicide*. Bristol: University of Bristol, 2000.
- 4 Crawford MJ, Prince M. Increasing rates of suicide in young men in England during the 1980s: the importance of social context. *Soc Sci Med* 1999;**49**:1419–23.
- 5 Whitley E, Gunnell D, Dorling D, et al. Ecological study of social fragmentation, poverty, and suicide. *BMJ* 1999;**319**:1034–7.
- 6 McLoone P. Suicide and deprivation in Scotland. *BMJ* 1996;**312**:543–4.
- 7 Congdon P. Suicide and parasuicide in London: a small-area study. *Urban Stud* 1996;**33**:137–58.
- 8 Ashford JR, Lawrence PA. Aspects of the epidemiology of suicide in England and Wales. *Int J Epidemiol* 1976;**5**:133–44.
- 9 Odland J. *Spatial autocorrelation*. California: Sage, 1988.
- 10 Besag J, Newell J. The detection of clusters in rare disease. *J R Stat Soc A* 1991;**154**:143–55.
- 11 Moore DA, Carpenter TE. Spatial analytical methods and geographical information system: use in health research and epidemiology. *Epidemiol Rev* 1999;**21**:143–61.
- 12 Bithell JF. Geographical analysis. In: Armitage P, Colton T, eds. *International encyclopaedia of biostatistics*. Chichester: Wiley, 1998:1701–16.
- 13 Congdon P. A multivariate model for spatio-temporal health outcomes with an application to suicide mortality. *Geogr Anal* 2004;**33**:234–58.
- 14 Elliott P, Best N. Geographical patterns of disease. In: Armitage P, Colton T, eds. *International encyclopaedia of biostatistics*. Chichester: Wiley, 1998:1694–701.
- 15 Clayton DG, Bernardinelli L, Montomoli C. Spatial correlation in ecological analysis. *Int J Epidemiol* 1993;**22**:1193–202.
- 16 National Confidential Inquiry into Suicide and Homicide by People with Mental Illness. *Safer services*. London: Stationery Office, 1999.
- 17 World Health Organization. *The ninth revision of the international classification of disease and related health problems (ICD-9)*. Geneva: WHO, 1978.
- 18 Lovett A, Haynes R, Bentham G, et al. Improving health needs assessment using patient register information in a GIS. In: Gatrell A, Layton M, eds. *GIS and health*. London: Taylor & Francis, 1998:191–203.
- 19 Office for the National Statistics. *Gazetteer of the old and new geographies of the United Kingdom*. London: ONS, 1999.
- 20 Rezaeian M, Dunn G, St Leger S, et al. The production and interpretation of disease maps: a methodological case-study. *Soc Psychiatry Psychiatr Epidemiol* 2004;**39**:947–54.
- 21 Chappell R. ONS procedures for compiling population estimates at sub-national level. In: Arnold R, Elliott P, Wakefield J, et al, eds. *Population counts in small areas: implications for studies of environment and health*. London: Office for the National Statistics, 1999:25–35.
- 22 Department of the Environment, Transport and the Regions. *Indices of deprivation 2000*. London: DETR, 2000.
- 23 Moran PAP. The interpretation of statistical maps. *J R Stat Soc B* 1948;**10**:243–51.
- 24 Geary RC. The contiguity ratio and statistical mapping. *Incorporated Stat* 1954;**5**:115–45.
- 25 Everitt BSE. *The Cambridge dictionary of statistics in the medical sciences*. Cambridge: Cambridge University Press, 1995.
- 26 Gerstman BB. *Epidemiology kept simple, An introduction to classic and modern epidemiology*. New York: Wiley-Liss, 1998.
- 27 Diggle PJ. Overview of statistical methods for disease mapping and its relation to cluster detection, and spatial variation in risk. In: Elliott P, Wakefield JC, Best NG, et al, eds. *Spatial epidemiology, methods and applications*. Oxford: Oxford University Press, 2000:87–103.
- 28 Johnson NL, Kotz S, Kemp AW. *Univariate discrete distributions*. New York: Wiley, 1992.
- 29 Breslow NE. Extra-Poisson variation in log-linear models. *Appl Stat* 1984;**33**:38–44.
- 30 STATA Corp. *Stata statistical software: release 6.0*. College Station, TX: Stata Corporation, 1999.
- 31 Gatrell AC, Bailey TC. Interactive spatial data analysis in medical geography. *Soc Sci Med* 1996;**42**:843–55.
- 32 Richardson S. Statistical methods for geographical correlation studies. In: Elliott P, Cuzik J, English D, et al, eds. *Geographical and environmental epidemiology—methods for small area studies*. Oxford: Oxford University Press, 1996:181–204.
- 33 Kleinbaum DG, Kupper LL, Morgenstern H. *Epidemiologic research: principles and quantitative methods*. New York: Van Nostrand Reinhold, 1982.
- 34 Morgenstern H. Uses of ecological analysis in epidemiologic research. *Am J Public Health* 1982;**72**:1336–43.
- 35 Richardson S, Monfort C. Ecological correlation studies. In: Elliott P, Wakefield JC, Best NG, et al, eds. *Spatial epidemiology, methods and applications*. Oxford: Oxford University Press, 2000:205–20.
- 36 Greenland S. Ecological versus individual-level sources of bias in ecologic estimates of contextual health effects. *Int J Epidemiol* 2001;**30**:1343–50.
- 37 Morgenstern H. Ecological studies in epidemiology: concepts, principals, and methods. *Ann Rev Public Health* 1995;**16**:61–8.
- 38 Lorant V, Thomas I, Delège D, et al. Deprivation and mortality: the implications of spatial autocorrelation for health resources allocation. *Soc Sci Med* 2001;**53**:1711–19.
- 39 Rezaeian M, Dunn G, St Leger S, et al. The ecological association between suicide rates and indices of deprivation in English local authorities. *Soc Psychiatry Psychiatr Epidemiol* 2005;**40**:785–91.
- 40 Wasserman IM, Stack S. Geographical spatial autocorrelation and United States suicide patterns. *Arch Suicide Res* 1995;**1**:121–9.
- 41 Lester D. Geophysical variables and behaviour: LV1. The spatial autocorrelation of States' suicide and homicide rates. *Percept Mot Skills* 1989;**68**:218.
- 42 Verheij RA. Explaining urban-rural variations in health: a review of interactions between individual and environment. *Soc Sci Med* 1996;**42**:923–35.
- 43 Morgenstern H. Ecological studies. In: Rothman KJ, Greenland S, eds. *Modern epidemiology*. Philadelphia: Lippincott-Raven, 1998:459–80.
- 44 Bentham G. Migration and morbidity: implication of geographical studies. *Soc Sci Med* 1988;**26**:49–54.
- 45 Hawton K, Harriss L, Hodder K, et al. The influence of the economic and social environment on deliberate self-harm and suicide: an ecological and person-based study. *Psychol Med* 2001;**31**:827–36.
- 46 Curtis S, Copeland A, Fagg J, et al. The ecological relationship between deprivation, social isolation and rates of hospital admission for acute psychiatric care: a comparison of London and New York City. *Health Place* 2004;**10**:117–28.
- 47 Sloggett A, Joshi H. Higher mortality in deprived areas: community or personal disadvantage? *BMJ* 1994;**309**:1470–4.
- 48 Department of Health. *National suicide prevention strategy for England*. London: Stationery Office, 2002.