Socioeconomic status and injury mortality: individual and neighbourhood determinants

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Abstract

***Study objective*—This study examined both individual and neighbourhood correlates of injury mortality to better understand the contribution of socioeconomic status to cause specific injury mortality. Of particular interest was whether neighbourhood effects remained after adjusting for individual demographic characteristics and socioeconomic status.**

***Design*—Census tract data (measuring small area socioeconomic status, racial concentration, residential stability, urbanisation, and family structure) was merged with the National Health Interview Survey (NHIS) and a file that links the respondents to subsequent follow up of vital status and cause of death data. Cox proportional hazards models were specified to determine individual and neighbourhood effects on homicide, suicide, motor vehicle deaths, and other external causes. Variances are adjusted for the clustered sample design of the NHIS.**

***Setting*—United States, 1987–1994, with follow up to the end of 1995.**

***Participants*—From a sample of 472 364 persons ages 18–64, there were 1195 injury related deaths over the follow up period.**

***Main results*—Individual level effects were generally robust to the inclusion of neighbourhood level variables in the models. Neighbourhood characteristics had independent effects on the outcome even after adjustment for individual variability. For example, there was approximately a two-fold increased risk of homicide associated with living in a neighborhood characterised by low socioeconomic status, after adjusting for individual demographic and socioeconomic characteristics.**

***Conclusions*—Social inequalities in injury mortality exist for both persons and places. Policies or interventions aimed at preventing or controlling injuries should take into account not only the socioeconomic characteristics of people but also of the places in which they live.**

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Recent research in the area of socioeconomic disparities in health has focused on the role of the residential environment in determining health. A growing body of literature has demonstrated that characteristics of communities where people live, such as family stability, housing conditions, income and wealth, crime, unemployment, segregation, and political empowerment, influence health outcomes and behaviour.[1–6] Social and economic characteristics of a community determine, in part, local access to goods and services, the built environment, the level of residential stability, crime, social norms, and the ability to maintain social control over individual behaviour. These analyses take into account the social factors and individual characteristics that contribute to individual health outcomes. The basic goal of most of this research is to differentiate between individual risk and the broader societal sources of risk.

A central hypothesis that drives much of the contextual analysis of social inequalities and health is that area characteristics represent more than simply the sum of its parts (for example, the aggregation of individual characteristics).[7] For instance, neighbourhood level economic segregation is hypothesised to affect all members of a community, regardless of their individual economic standing. Thus, individual socioeconomic position may not protect the health of people who are well off when they live in poor environments. A number of recent studies have demonstrated contextual effects on the health of people using the neighbourhood (that is, census tract, postcode sector, ward) as the context. For example, independent neighbourhood effects have been found for residential segregation on all cause mortality,[4] area socioeconomic status[6] and deprivation[8] on several adult health measures; area deprivation and cardiovascular disease risk factors and mortality[9]; and female headship rates and heart disease mortality in women.[10] The consistent findings of these studies strongly suggest that characteristics of places are not simply proxies for individual characteristics; indeed, we should be focusing on both people and places.[11]

Death from external causes such as intentional and unintentional injury has the most plausible link to the residential environment as, by definition, the source of injury is located outside the person. External cause mortality, however, is not well explored using techniques of the type described above. A conceptual model developed initially to understand motor vehicle injuries, the Haddon matrix, describes several factors related to the risk of injury: human, agent, and the environment (physical and socioeconomic).[12] This descriptive framework can also be extended to other causes of injury death. We are particularly interested in the impact of the residential socioeconomic environment on the risk of dying from external causes. To date, there has been no comprehensive study that focuses on the joint contribution of individual and community socioeconomic

characteristics to a person's risk of death from injury. Several studies do, however, suggest that aggregate measures are related to the overall risk of an injury death.[13–17] For example, Baker *et al* found that low per capita income in the county of residence is related to higher homicide and unintentional fatal injury rates for the US and that unintentional injury rates are higher in rural compared with urban areas.[13] Other findings regarding injury mortality have been based on specific geographical areas.[14–17]

The ecological studies discussed above suggest that geographical measures of socioeconomic conditions are related to aggregate injury mortality outcomes. We do not know, however, whether these measures have a direct effect on a person's mortality risk in the presence of individual covariates. The purpose of this paper is to bridge the gap in the literature between the individual and ecological levels regarding the relation between socioeconomic status and death because of injury. Firstly, we determine whether neighbourhood or community characteristics make an independent contribution to the risk of injury death for people. Secondly, we determine whether these effects act as a proxy for a person's socioeconomic status or persist in model specifications that include both individual and neighbourhood measures.

Methods

DATA

This analysis is based on three sources of data: the National Health Interview Survey (NHIS) 1987–1994, the National Health Interview Survey/Multiple Cause of Death Public Use Data file (NHIS/NDI) 1987–1995, and the 1990 US Population Census. The NHIS is a continuing annual household interview survey representative of the civilian non-institutionalised population of the United States.[18] Information is collected regarding health status, health conditions, sociodemographics, and other characteristics of each household member. For the purposes of this study, we restrict the analysis to adult respondents ages 18–64 (n=547 535), a population at high risk of injury mortality.

The NHIS/NDI file was produced by matching characteristics common to both the NHIS and the National Death Index, which contains the universe of death certificates and is searched from the date of interview through the end of 1995.[19] The probability matching methodology results in a score for each record based on the number of characteristics matched between the NHIS and the NDI and has been shown to be highly accurate.[20] Once matches are identified, death certificates are obtained from the states to ascertain cause of death information. The matched NHIS/NDI file contains person identification information, vital status, matching class and score, date of death, cause of death, and other information from the NDI.

Using date of interview from the NHIS file and date of death or censoring time from the NHIS/NDI, number of months or duration from time of interview until time of death or censoring (31 December 1995) was calculated. Injury deaths are defined as successful matches in the NHIS/NDI file with an ICD-9 E-code between 800 and 999. Deaths attributable to adverse events and medical misadventures (E930-E949, E870-E879) were subsequently excluded (n=52). Four outcomes were investigated: motor vehicle related deaths (E810-E825), suicide (E950-E959), homicide (E960-E978), and all other external causes (E800-E807, E826-E929, E980-E999). The other external cause category contains various causes of injury death (poisonings, falls, drownings, etc); however, the numbers were not sufficient to investigate each cause separately.

Each annual file of the NHIS from 1987–1994 also has the address of the respondents geocoded to 1990 census geography, which are used to link characteristics of the place of residence using census tract level data. About 13.7% (n=75 120) of the records were not successfully geocoded and were dropped from the analysis. The remaining NHIS respondents with geographical identifiers reside in 6179 different census tracts across the country. The 1990 Census data from Summary Tape Files 1A and 3A were used to construct the neighbourhood level variables. Census tracts, which are statistical rather than true geographical aggregates, were chosen to represent neighbourhoods because previous research found the tract to be a good approximation of the neighbourhood environment with reliable social and economic data available from the US Bureau of the Census. Census tracts include approximately 4000 people and the boundaries are delineated to encompass a relatively homogeneous population.[21 22]

The analysis includes only the sample of records without missing neighbourhood information reducing the sample size to 472 364 persons and 1195 injury deaths. The percentage distribution of total injury deaths by cause is as follows: 17% homicide, 23% suicide, 33% motor vehicle, 27% other external causes.

INDIVIDUAL LEVEL VARIABLES

Correlates at the individual level include age, sex, self reported race/ethnicity, marital status, income to needs ratio, educational attainment, employment status and occupation. The income to needs ratio is created by taking the midpoint of the income categories in the NHIS, and dividing by family size. All variables are coded categorically except for age. These variables have been shown to be reliable individual level predictors of mortality risk due to external causes.[13 23] Correlations between the measures of socioeconomic status (income to needs, educational attainment, occupational status) range between 0.16 and 0.59.

NEIGHBOURHOOD LEVEL VARIABLES

Census tract variables were selected to measure the economic standing of the community (blue collar, family income, poverty, education, housing value, crowded housing); residential and family stability (mobility, unemployment, vacant housing, female headship, divorced);

Table 1 Neighbourhood variables and definitions, 1990 US Census Tract level data

Socioeconomic status	
Family income	median income for all households
Poverty	proportion of persons whose annual income falls at or below 175% of the poverty line
Education	proportion of persons 25 years and over with less than a high school graduate education
Housing value	median value of owner occupied housing units
Crowded housing	proportion of households with more than one person per room
Blue collar	proportion of employed persons in service occupations, farming and fishing occupations, precision production, craft and repair occupations, and operators, fabricators, and labourers
Racial/ethnic concentration	
Black	proportion of all persons who are black
Hispanic	proportion of all persons who are Hispanic
Residential stability	
Mobility	proportion of persons ages 5 and older who lived in the same house for past five years
Unemployment	proportion of persons ages 16 and over who are unemployed
Housing tenure	proportion of occupied housing units that are rented
Family structure	
Female headship	proportion of families headed by women
Poor female headship	proportion of poor families which are headed by women
Divorced	proportion of persons ages 15 and over who are divorced or separated
Urbanisation	
Multi-unit housing	proportion of housing units with five or more units in structure
Urban	residence in an urban census tract

racial concentration (proportion black or Hispanic); and urbanisation (multi-unit housing, urban residence) of the neighbourhood. All variables are coded categorically using empirical quartiles to identify appropriate categories. Table 1 lists the neighbourhood variables and definitions.

ANALYTICAL METHOD

Continuous time event history methods are used with person months calculated based on month and year of survey and month and year of death or censoring. Cause specific injuries (motor vehicle, suicide, homicide, other external causes) are analysed separately using Cox proportional hazards models. Neighbourhood level variables are first added to a baseline model with individual demographic characteristics. The purpose of this step is to determine whether neighbourhood characteristics are correlated with injury outcomes. Next, individual socioeconomic status is introduced into the models to determine if neighbourhood conditions affect the risk of a fatal injury net of

Table 2 Sample characteristics, respondents to the National Health Interview Survey (1987–1994) and those who died of injury, aged 18–64, with follow up until 1995 and linked to the 1990 US Census*

		Those who died of injury (n=1195)			
Variables	*All respondents (SE)†*	*Homicide (SE)*	*Suicide (SE)*	*Motor vehicle (SE)*	*Other external (SE)*
Individual level					
Age (mean years)	38 (0.1)	31 (1.0)	38 (0.9)	37 (0.8)	39 (0.8)
Sex					
% men	49 (0.1)	73 (3.7)	78 (2.6)	66 (2.4)	79 (2.3)
% women	51 (0.1)	27 (3.7)	22 (2.6)	34 (2.4)	21 (2.3)
Race/ethnicity					
% Black, non-Hispanic	12 (0.5)	41 (4.0)	7 (1.4)	14 (1.9)	14 (2.2)
% Hispanic	4 (0.3)	3 (1.7)	1 (0.8)	3 (1.1)	3 (1.0)
% White, non-Hispanic‡	84 (0.6)	56 (4.2)	92 (1.5)	83 (2.1)	83 (2.4)
Marital status					
% divorced or separated	10 (0.1)	13 (2.3)	13 (2.1)	13 (1.8)	17 (2.1)
% never married	23 (0.3)	49 (4.3)	28 (2.7)	30 (2.6)	28 (2.9)
% widowed	2 (0.0)	1 (0.7)	4 (1.2)	3 (0.9)	3 (0.8)
% currently married	65 (0.3)	37 (4.2)	55 (3.1)	54 (2.8)	53 (3.0)
Education (mean years)	13 (0.0)	11 (0.2)	12 (0.2)	12 (0.2)	12 (0.2)
Income to needs (mean $)	13986 (99)	8738 (822)	14686 (732)	11209 (581)	9399 (569)
Occupation/employment status					
% blue collar	32 (0.3)	35 (3.7)	39 (2.9)	44 (2.7)	36 (2.7)
% unemployed	4 (0.1)	12 (2.7)	5 (1.5)	7 (1.3)	9 (1.7)
% not in labour force	22 (0.2)	35 (4.1)	26 (2.8)	21 (2.0)	35 (2.5)
% white collar	42 (0.3)	18 (2.6)	31 (2.7)	28 (2.4)	19 (2.3)
Neighbourhood level means§					
Family income ($)	36725 (236)	29133 (1051)	36143 (858)	33039 (779)	32426 (845)
Poverty	27 (0.3)	38 (1.2)	26 (1.0)	31 (1.0)	32 (1.1)
Education	25 (0.3)	35 (1.3)	25 (0.9)	29 (0.8)	30 (0.9)
Housing value ($)	100491 (1615)	74827 (5245)	97561 (4891)	85177 (3374)	94202 (6128)
Crowded housing	5 (0.2)	10 (0.8)	4 (0.3)	6 (0.5)	6 (0.6)
Blue collar	44 (0.3)	50 (1.0)	44 (0.9)	49 (0.8)	49 (0.9)
Black	12 (0.5)	31 (2.5)	9 (1.0)	13 (1.1)	16 (1.4)
Hispanic	8 (0.4)	14 (1.9)	6 (0.8)	8 (1.0)	9 (1.1)
Mobility	55 (0.3)	55 (0.8)	54 (0.8)	56 (0.8)	56 (0.9)
Unemployment	4 (0.1)	6 (0.3)	4 (0.1)	5 (0.2)	5 (0.2)
Housing tenure	35 (0.3)	43 (2.0)	35 (1.4)	34 (1.1)	38 (1.4)
Female headship	12 (0.1)	19 (0.9)	11 (0.3)	12 (0.4)	13 (0.5)
Poor female headship	5 (0.1)	10 (0.9)	4 (0.3)	6 (0.4)	6 (0.5)
Divorced	11 (0.1)	13 (0.4)	11 (0.3)	10 (0.3)	11 (0.3)
Multi-unit housing	16 (0.3)	19 (2.4)	16 (1.6)	13 (1.0)	16 (1.5)
Urban	84 (0.6)	91 (2.2)	82 (2.6)	76 (2.1)	76 (2.7)
Observations	472364	208	278	392	317

*Means, percentages, and standard errors adjusted for sample design, percentages may not add to 100 because of rounding. †SE = standard eror. ‡Includes other race. §Defined in table 1; per cent in group unless indicated.

Table 3 Weighted individual level hazard ratios‡ for injury mortality for persons aged 18–64 who responded to the National Health Interview Survey 1987–1994 with follow up until 1995 and linked to the 1990 US Census (n=472 364)

	Homicide	*Suicide*	*Motor vehicle*	*Other external*
Age§	0.97**	1.00	1.00	1.01*
Gender				
male	3.35†	4.41†	2.06†	4.92†
female	1.00	1.00	1.00	1.00
Race/ethnicity				
black, non-Hispanic	3.62†	0.47**	0.98	0.89
Hispanic	1.26	0.34	0.99	0.81
white, non-Hispanic¶	1.00	1.00	1.00	1.00
Marital status				
divorced/separated	2.01**	1.83**	1.69**	2.33†
never married	1.69*	1.37	1.48**	1.48*
widowed	1.18	3.55**	1.92*	1.71
currently married	1.00	1.00	1.00	1.00
Income to needs				
missing income	1.94	0.73	1.18	1.86*
<$6250	1.98	0.78	1.51*	2.45**
$6250–$11 250	2.28	0.89	1.01	1.95*
$11 250–$18 750	1.82	0.85	1.14	1.23
$18 750–$75 000	1.00	1.00	1.00	1.00
Educational attainment				
less than high school	1.98†	1.21	1.46**	1.41*
high school graduate	1.00	1.00	1.00	1.00
Employment/occupational status				
blue collar	1.35	1.25	1.50**	1.45*
unemployed	2.99†	1.61	1.77*	3.19†
not in labour force	2.52†	2.05†	1.25	2.85†
white collar	1.00	1.00	1.00	1.00
Number of deaths	208	278	392	317

‡Estimates adjusted for sample design. §For each additional year. ¶Includes other race. *p<0.05 **p<0.01 †p<0.0001.

individual socioeconomic and demographic risk factors. If significant neighbourhood effects remain after the reintroduction of individual covariates, strong evidence exists that those effects are real and not attributable to population composition. Each neighbourhood characteristic is tested in a separate empirical model because of extreme multicolinearity between the neighbourhood variables.

The National Health Interview Survey is a complex multistage probability sample that yields clustered observations. Because the sample is selected to be nationally representative, households are not chosen in a simple random sample. The households are clustered because at each stage of the sample selection process, geographical areas are selected and eventually targeted for interview. The survey design effects that result should be accounted for when producing estimates or multivariate models.[24] For these analyses, the design effects are accounted for by using SUDAAN version 7.11 (Research Triangle Institute, 1997), a software product, on the final models, which accounts for the sampling design to produce valid variance estimates. It is also true that multilevel research designs such as this introduce similar difficulties with statistical inference (related to clustering of people within census tracts in this case) that the use of specialised software also helps alleviate.[25]

Results

Table 2 contains the characteristics of the sample. Persons who died of injury tended to be male, unmarried, and of lower income (except for suicide), and educational attainment and not in white collar occupations compared with the total sample. Persons who died from homicide were more likely to be black and of younger age while those who died of suicide were more likely to be white. The census tract characteristics indicate that persons who died of injury generally resided in neighbourhoods with lower socioeconomic status, higher racial concentration, and greater residential and family instability compared with the total sample.

KEY POINTS
- Individual and neighbourhood characteristics are independently associated with the risk of injury mortality.
- Individual characteristics are generally robust to the inclusion of neighbourhood characteristics in the models.
- Individual race and socioeconomic status differences in the risk of homicide are mediated through the residential environment.

INDIVIDUAL LEVEL MODELS

Table 3 contains the adjusted risk ratios for the four injury mortality outcomes resulting from the Cox proportional hazards analyses in SUDAAN for respondents of the NHIS linked to the NDI and census data. From the models for homicide, individual socioeconomic status decreases the hazard ratios for black persons from 5.14 in the models adjusted only for age, gender, and race/ethnicity (not shown) to 3.62 in the models with additional adjustment for marital and socioeconomic status. While there is essentially no difference in homicide risk by income, persons with low education and those who are unemployed or out of the labour force are at significantly increased risk of death from homicide. In the individual level models for suicide, there is a strong increased risk associated with being male, white, previously married, and out of the labour force. Men are at twice the risk for motor vehicle mortality compared with women. Unmarried, low income, unemployed, blue collar, and persons without a high school degree are all at significantly increased risk of motor vehicle fatalities. For other external causes of death, which include unintentional poisoning, suffocation, drowning, and falls, socioeconomic status, marital status, and employment status are each associated with the risk of death from these causes. These results are consistent with previous research on external causes of death.

NEIGHBOURHOOD LEVEL MODELS

Table 4 presents the neighbourhood level hazard ratio estimates adjusted for individual demographic and socioeconomic characteristics and the NHIS sample design. One important consideration in multilevel research is that the neighbourhood effects not be confounded by a mis-specified individual level model. Because of space considerations, we have not included the individual level hazard estimates in table 4 and the full tables are available from the authors upon request. No model is presented with more than one neighbourhood variable because of extreme multicolinearity between neighbourhood characteristics. Thus, each neighbourhood variable is included in the

Table 4 Weighted neighbourhood level hazard ratios‡ for injury mortality by cause of death and type of model used for persons aged 18–64 who responded to the National Health Interview Survey 1987–1994 with follow up until 1995 and linked to the 1990 US Census (n=472 364)

	Homicide		*Suicide*		*Motor vehicle*		*Other external*	
	Demo§	*Full¶*	*Demo*	*Full*	*Demo*	*Full*	*Demo*	*Full*
Socioeconomic status								
Family income								
$0–25 953	3.96†	2.66**	1.08	0.95	2.23†	1.73**	2.61†	1.46
$25 953–33 271	2.02*	1.64	1.53*	1.46*	2.19†	1.89†	1.78**	1.24
$33 271–42 933	2.99**	2.67**	1.04	1.01	1.50*	1.38*	1.60*	1.28
$42 933–150 001	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Poverty								
0–13.6%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13.6–24.8%	2.03**	1.81*	0.99	0.95	1.24	1.13	1.47*	1.20
24.8–38.1%	1.61	1.27	1.53*	1.44*	2.26†	1.93†	2.06†	1.44*
38.1–100%	3.08†	2.00*	1.05	0.91	1.94**	1.48*	2.81†	1.57*
Education								
0–14.9%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14.9–24.0%	2.05*	1.92*	0.90	0.87	1.39	1.30	1.25	1.07
24.0–35.6%	2.34**	1.99*	1.18	1.10	1.84**	1.60**	1.60*	1.19
35.6–83.1%	3.92†	2.73**	0.90	0.77	2.26†	1.75**	2.29†	1.36
Housing value								
$0–46 200	2.21**	1.65*	1.28	1.22	1.91†	1.60**	1.65**	1.10
$46 200–68 400	1.59	1.39	0.99	0.98	1.63**	1.49**	1.13	0.90
$68 400–121 000	1.70*	1.61	1.02	1.03	1.29	1.24	0.81	0.72
$121 000–500 001	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Crowded housing								
0–1.2%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.2–2.7%	1.29	1.20	1.30	1.27	1.16	1.08	1.99**	1.78**
2.7–5.8%	1.31	1.11	1.45*	1.38	1.43*	1.27	2.53†	2.07**
5.8–69.4%	2.24**	1.70*	0.96	0.86	1.42*	1.16	2.75†	1.96**
Blue collar								
0–33.9%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
33.9–45.7%	1.64	1.46	0.94	0.91	1.55**	1.43*	1.13	0.92
45.7–56.7%	1.69	1.33	1.12	1.05	2.07†	1.80†	1.63**	1.17
56.7–100%	2.32**	1.64	1.00	0.92	2.32†	1.88†	1.92†	1.21
Racial concentration								
Black								
0–0.4%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.4–2.3%	1.18	1.23	1.10	1.10	0.71*	0.73*	0.98	1.06
2.3–13.1%	1.07	1.06	1.48*	1.43*	0.74*	0.74*	1.18	1.17
13.1–100%	2.51**	2.16**	1.20	1.11	0.96	0.87	1.42	1.20
Hispanic								
0–0.5%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5–1.7%	1.14	1.27	1.38	1.40	0.81	0.86	0.58**	0.64**
1.7–6.7%	0.81	0.94	1.19	1.20	0.73*	0.79	0.73	0.84
6.7–98.0%	1.37	1.43	1.17	1.12	0.75	0.74	0.94	0.93
Residential stability								
Mobility								
0–48.3%	1.18	1.26	1.42	1.38	0.80	0.80	0.78	0.77
48.3–57.0%	1.41	1.48	1.40	1.40	0.97	0.98	0.86	0.87
57.0–64.4%	1.31	1.36	1.45*	1.45*	1.04	1.05	0.82	0.83
64.4–90.4%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unemployment								
0–2.6%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2.6–3.7%	0.84	0.77	1.04	1.00	1.00	0.94	1.51*	1.32
3.7–5.4%	1.07	0.91	1.24	1.16	1.48**	1.32	1.64**	1.31
5.4–26.9%	1.83*	1.29	0.97	0.83	1.61**	1.27	2.27†	1.44
Housing tenure								
0–19.2%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19.2–29.2%	1.62	1.53	1.20	1.17	1.00	0.95	0.86	0.78
29.2–46.9%	1.61	1.49	1.25	1.19	1.03	0.95	0.83	0.73
46.9–100%	1.82*	1.59	1.36	1.21	0.82	0.72*	1.30	1.02
Family structure								
Female headship								
0–6.9%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.9–9.7%	1.86	1.82	1.23	1.21	0.95	0.92	1.11	1.07
9.7–14.4%	3.05**	2.79**	1.47*	1.40	1.01	0.93	1.18	1.03
14.4–80.1	4.59†	3.50**	1.18	1.05	0.99	0.80	1.68**	1.17
Poor female headship								
0–1.0%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.0–2.6%	2.11*	1.93*	1.22	1.20	1.52**	1.41*	1.68*	1.44
2.6–6.3%	1.85*	1.55	1.62*	1.54*	1.69**	1.47**	1.61*	1.21
6.3–74.4%	3.30†	2.31**	1.20	1.06	1.87†	1.46*	2.47†	1.52
Divorced								
0–7.5%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7.5–10.1%	2.67**	2.57**	0.94	0.92	1.01	0.96	1.28	1.18
10.1–13.6%	1.86	1.79	1.27	1.22	1.05	0.98	1.07	0.96
13.6–38.7%	3.00**	2.61**	1.45	1.32	0.83	0.73	1.42	1.13
Urbanisation								
Multi-unit housing								
0–1.5%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.5–7.7%	1.26	1.26	1.13	1.12	0.80	0.80	1.08	1.07
7.7–21.9%	1.40	1.46	0.95	0.93	0.65**	0.66**	0.76	0.78
21.9–100	1.16	1.21	1.02	0.96	0.54**	0.54**	0.95	0.95
Urban								
Yes	1.48	1.62	0.90	0.88	0.60†	0.64†	0.62**	0.68**
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

‡Estimates are adjusted for sample design and each neighbourhood variable is entered separately. §Demo = demographic model adjusting for age, gender, race/ethnicity. ¶Full = full model adjusting for demographic characteristics, marital status, income to needs, educational attainment, employment/occupational status. *p<0.05 **p<0.01 †p<0.0001.

two models with the first risk ratio adjusted for individual level demographic variables (age, gender, and race/ethnicity) and the second for all individual covariates (age, gender, race/ethnicity, marital status, and socioeconomic status). The hazard ratios are shown for both models to demonstrate how the relations can change after adjustment for individual socioeconomic status measures in addition to simply age, gender, and race/ethnicity.

Homicide

The measures of neighbourhood socioeconomic status operate in the expected direction for homicide. Residence in neighbourhoods with low family incomes, high poverty, high proportions of poorly educated persons, low housing values, and high proportions of crowded housing, each significantly increase a person's risk of death attributable to homicide, after controlling for demographic and socioeconomic characteristics. Increased residential concentration of blacks also leads to higher risk of death from homicide regardless of a person's race. Family structure, especially female headship, is related to the risk of homicide in a gradient fashion where the risk of death increases as the proportion of female headed or poor female headed households and divorced/separated persons increases. All the relations were attenuated when the models were adjusted for individual socioeconomic status. This suggests that a proportion of the neighbourhood effect shown in the first column is compositional but the remainder can be attributed to neighbourhood socioeconomic conditions that are external to the individual. There was no adjusted increased risk for persons living in urban areas despite accepted wisdom of the dangers of urban areas.

Suicide

Five neighbourhood characteristics had significant effects on the risk of suicide. The individual level hazard ratios remain essentially unchanged in the presence of neighbourhood characteristics. For residential mobility, family income, poverty, black racial concentration, and poor female headed households, the significantly increased risks of suicide are seen at intermediate levels only. There is little or no attenuation with the introduction of individual socioeconomic status.

Motor vehicle

The results for motor vehicle fatalities show that residents of neighbourhoods with lower socioeconomic status and higher proportions of poor households headed by women are at higher risk. In contrast, persons living in urban areas or highly racially segregated neighbourhoods are at lower risk. As in the models for homicide, the hazard ratios for low socioeconomic status and unemployed persons are slightly attenuated (not shown).

Other external causes

The risk of death from other external causes is increased for people living in poor and crowded areas, while persons are at decreased risk in urban areas and neighbourhoods with a high percentage of Hispanic persons. Individual socioeconomic status seems to account for much of the observed neighbourhood effects or attenuates the effects where they remain important covariates. The individual hazard ratios for socioeconomic status are attenuated in the contextual models (not shown).

Discussion

In this research, we disentangle the effects of both socioeconomic status of people and that of neighbourhoods on individual injury mortality risk. The analysis is to our knowledge unique in the field of injury mortality research and represents an important step toward understanding how disadvantages, measured for both people and places, can operate to increase mortality from external causes. The findings presented here support the hypothesis that both individual and neighbourhood characteristics each contribute independently to the risk of injury death. The contribution, however, varies considerably by external cause.

For homicide, even after adjusting for individual and neighbourhood socioeconomic status, black adults are still at increased risk compared with whites although the magnitude is reduced considerably when neighbourhood characteristics are introduced. The neighbourhood effects suggest that social, economic, and structural conditions in the community (for example, availability or ownership of firearms) are important determinants of homicide. Individual racial and socioeconomic differences are probably explained by mechanisms that work through the residential environment. Indeed, Centerwall[15] found that when household crowding is used as a measured of neighbourhood socioeconomic conditions, there were no statistical differences in domestic homicide by race.

The risk of suicide is statistically unrelated to individual socioeconomic status. This is in contrast with the findings of Kellermann *et al* that demonstrate an increased risk of all suicides for persons with limited education.[27] Their findings, however, are based on a population from a specific geographical area that restricts their ability to generalise to the nation. We find about a 50% increased risk for persons living in neighbourhoods with the following characteristics—low socioeconomic status, high racial concentration, and high residential and family instability. These places may increase feelings of hopelessness or social isolation for people who may be considering suicide and, thus, contribute to the increased risk. Blacks are at significantly lower risk of suicide compared with whites even after controlling for individual socioeconomic status, marital status, and neighbourhood characteristics. This remains relatively unexplored but may be because of cultural differences to the resolution of depressive episodes.

Neighbourhood socioeconomic status, racial concentration, and family structure, net of individual variability, are related to motor vehicle mortality. Not surprisingly, persons living in urban areas were found to be at decreased risk

reflecting decreased exposure to traffic. This is consistent with the results of a study that examined geographical patterns of motor vehicle mortality by county and found an inverse relation with population density, most probably related to the increased distances travelled in rural areas[28] and less access to nearby medical care, especially trauma facilities. The neighbourhood effects suggest that persons in high risk rural areas may have less access to newer, more crashworthy cars and safer roads, have greater distances to travel, and more exposure to hazardous driving conditions and behaviour, which could effect all residents of a community. The protective effect of higher black racial concentration may be attributable to its high correlation with urbanisation.

One of the most obvious effects of the external environment is that experienced by those living in rural (non-urban) settings. For other external causes, those living in urban areas are protected, probably in part because of the high risk of fatalities in rural areas from farm equipment, less access to medical care, and other risks associated with working in the outdoors. We speculate that the increased risk associated with living in areas characterised by concentrated poverty and crowded housing is related to the hazardous physical environment (for example, deaths attributable to falls), poor fire protection and use of equipment such as ovens or space heaters for heating (for example, deaths resulting from fire or suffocation), hazardous work environments (for example, occupational fatalities from various causes), or limited access to safe recreational facilities (for example, deaths caused by drowning).

Family structure and residential stability are often used to measure social disorganisation or a community's inability to maintain effective social controls.[29] With higher levels of mobility and single parent households, it may be more difficult for a community to collectively sustain a sense of empowerment or control the appearance of their neighbourhood or the behaviour of its residents. Injury mortality is often viewed as a consequence of the inability of people to protect themselves from intentional or unintentional harm. The deterioration of community functions, both formal and informal, associated with social disorganisation increases a persons exposure to the risk of harm. Such factors are believed to be in part responsible for the sudden increase in injury mortality in Russia over recent years.[30] This research demonstrates that similar people (based on demographic and socioeconomic characteristics), suffer disproportionately in disorganised environments such as those described here.

Favourable socioeconomic conditions reflect an area's material resources and access to high quality municipal services, such as fire and police protection, safe roads, and recreational facilities. For instance, regardless of a person's socioeconomic status, this study shows that that person is more likely to die of an injury from any cause if they reside in an area with high poverty levels. Affluent neighbourhoods have lower crime rates, restrict access to cars and "undesirable" neighbours, and their residents are less likely to tolerate deviant behaviour, each of which may be protective factors against injury mortality.

Additional analyses were conducted to assess the degree to which missing geocodes affected inferences (analyses not shown). Respondents with missing geocodes were more likely to be younger, white or Hispanic, married, and of higher socioeconomic status when compared with respondents whose records could be geocoded in part because these reflect new suburban developments not assigned geocodes. In addition, we ran the individual level models with the full sample (including persons with missing geocodes) to assess the degree to which the individual level estimates were affected by the exclusions. Minor differences were found.

There are several limitations in this study. Neighbourhood characteristics are measured in 1990 whereas the date of interview is from 1987 to 1994. This presents the possibility of simultaneity bias as the neighbourhood characteristics in some cases are measured after a person has died. However, this is not expected to be a major concern because neighbourhoods generally do not change significantly over the short time period involved.[31] What is perhaps more problematic conceptually is that neighbourhood measures are static; that is, we have no information regarding the historical context of neighbourhoods, how they are changing, or how long people have been exposed to their neighbourhood environments.[32] This analysis essentially represents a snapshot of the effects of neighbourhood conditions on injury mortality outcomes.

Thirdly, there was no way to distinguish between occupational injuries. This is important because people working in high risk occupations and industries have different risk profiles than the rest of the population and may be in part responsible for increased motor vehicle rates in blue collar workers.[33] The analysis would be strengthened if it were possible to separate the work related cases from the "other external cause" category. However, using a method[34] to identify causes likely to be industrial, a small proportion of other external causes were likely to be work related (14%) and separate unpublished analyses have shown that overall only 4.7% of all injury deaths in our age group occurred "at work."

The main strength of the study is the ability to estimate jointly the individual and neighbourhood level determinants on an individual level outcome. We used comprehensive measures of individual socioeconomic status to minimise observing neighbourhood effects attributable to confounding.[35] This research links three national and reliable datasets in a longitudinal design that strengthens our external validity, and the ability to generalise to the population as a whole.

Future research needs to analyse neighbourhood effects for women and men separately. Similarly, cross level interaction effects ought to be investigated to determine whether neighbourhood effects vary by individual gender, race, ethnicity, marital status, and

socioeconomic status. For instance, given the very different neighbourhood environments of blacks compared with whites, it is reasonable to expect the neighbourhood effects for homicide to have different magnitudes for the two groups. Innovative and thoughtful approaches to characterising neighbourhoods is sorely needed to understand the most important modifiable determinants of injury risk. Finally, additional research is needed to identify the intervening mechanisms between neighbourhood characteristics and injury. For example, what social processes are involved in how unfavourable socioeconomic neighbourhood conditions result in increased injury risk to people and how can they be modified?[32]

Identifying neighbourhood effects has important policy implications as characteristics of a peron's local social and economic environment can influence injury risk. Thus, social policies, planning practices, and interventions at the community level focusing both on places and people are likely to be more effective injury control strategies than those focusing on changing individual behaviour. Communities ought to hold local government policymakers and planners accountable to ensure that goods and services are efficiently distributed according to need. In addition, broader social and economic policies related to taxation, the minimum wage, labour markets, and social capital are likely to have a positive impact on the health and well being of residents of disadvantaged communities and their injury risk. These measures serve to promote a shift in focus from people to intervening on places using the tools of public health practice and advocacy.

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