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Socioeconomic status and deaths due to unintentional injury among children: A socio-spatial analysis in Taiwan

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Abstract

In Taiwan, unintentional injury is the leading cause of death among children <10 years old. Low socioeconomic status is a risk factor associated with a high prevalence of injuries and our study aimed to explore the geographic distribution of mortality due to unintentional injury in this age group assessing the association between this type of injury on the one hand and socioeconomic disadvantages and family structure on the other using cluster and spatial regression analyses. Using exploratory factor analysis, we assembled nine socioeconomic variables into four composite factors including area-level poverty, family burden, family fragility and unemployment. We found significant spatial clusters of childhood deaths due to unintentional injury and identified three major causes of death involved, *i.e.* traffic accidents, drowning and suffocation. Significant associations were found between death due to unintentional injury and area-level social disadvantages including poverty, family fragility, family economic burden and unemployment, while controlling for spatial autocorrelation. Our conclusion is that socioeconomic disadvantages need to be addressed to reduce the number of deaths due to childhood unintentional injury.

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See online Appendix for additional Figures.

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Introduction

The Global Burden of Disease Study 2016, issued by the Institute for Health Metrics and Evaluation, University of Washington, Washington DC, USA in collaboration with the World Health Organization (WHO) accounted more than 3 million deaths to unintentional injury in 2015 with nearly 20% of them in children under the age of 15. This amounts to 10% of the world's child mortality in 2015 excluding deaths related to perinatal insult (WHO, 2016). The 2015 crude injury mortality rate among children aged 0-9 years in Taiwan was 30.3 per 100,000 population and injuries had caused one-fourth of these deaths (Ministry of Health and Welfare, Taiwan, 2016). Between 2011 and 2015, the rate of mortality due to injury decreased from 10.2 to 8.8 per 100,000 populations; however, mortality due to injury varied greatly in different areas, from 1.4 to 108.5 per 100,000 populations in 2015 (Ministry of Health and Welfare, Taiwan, 2018).

Unintentional injury is the major cause of death among children worldwide and they are always externally caused, *e.g.*, motor vehicle injury, suffocation, drowning or due to burns and falls. Physical and social environment can influence the injury rate. With regard to pedestrian injury, more years spent in the family residence and more hours/days spent in school decrease the risk of road traffic injuries (Donroe *et al*., 2008). In addition, high traffic volume and high density of curb parking increase the risk of injury (Roberts *et al*., 1995). Low socioeconomic status (SES) has proved to be a strong predictor of childhood mortality due to injury and many studies have identified various risk factors of this occurring, including family poverty (Roberts *et al*., 1996; Singh and Yu, 1996), family structure (Östberg, 1997; maternal education (Scholer *et al*., 1999; Blakely *et al*., 2003; Schnitzer and Ewigman, 2008), race and/or ethnic minority issues (Singh and Yu, 1996) and living in low-income communities (Durkin *et al*., 1994; Laing and Logan, 1999).

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Geographic inequalities in health are strongly attributable to variation in the underlying social and environmental condition in populations and disparities in social determinants of health among children have been well documented (Poulton *et al*., 2002; Cheng *et al*., 2009). Recently, child mortality due to injury in relation to inequalities associated with the geographical area of residence have acquired importance because there are contextual factors at the spatial level that can explain health outcomes regardless of individual factors. In the US, for example, children in the most deprived socioeconomic quintile of the counties have been shown to have a 69% higher rate of mortality due to unintentional injury than children in the least deprived socioeconomic quintile (Singh and Kogan, 2007). Community factors that influence unintentional injuries are mostly correlated with income and population density (Baker *et al*., 1987), degree of urbanization (Yang *et al*., 1997) as well as education and family structure (Cubbin *et al*., 2000). Data from Canada suggest that aboriginal ethnicity also is a risk factor in unintentional fall injury and this has multiple interactions with the number of people per room in the home and participation in the labour force instead of residence location (Jin *et al*., 2017) although the mechanism by which socioeconomic factors exert an effect on health are not always clear, poverty, low educational attainment and relative deprivation can increase the exposure to environmental hazards. However, when developing interventions aimed at reducing such inequalities, identification of patterns with respect to geographical areas with poor levels of health and other socio-economic indicators would better support outcomes than one-size-fits-all approaches.

Injury remains the leading cause of death among Taiwan children and the rate is higher than in most countries belonging to the Organization for Economic Co-operation and Development that includes Japan and Korea, countries with a similar cultural background to that of Taiwan (Liang *et al*., 2016). To date, however, no small-area analysis of child mortality due to unintentional injury in Taiwan has been published. Our study therefore aimed to identify township-level inequalities in child unintentional mortality due to injury using the national death statistic registry programme. We used spatial analysis to study patterns in the rates of age-adjusted child mortality due to injury at the level of townships and small cities invoking tests for the potential associations between mortality and place of residence, demography and socioeconomic characteristics.

Materials and Methods

Mortality records

Vital statistics on data mortality due to injury for the period 2000-2007 were obtained from the Ministry of Health and Welfare of Taiwan. All unintentional deaths among children age 0-9 years were included in the analysis using the classification of International Classification of Diseases, Ninth Revision (ICD-9) external-cause -of-injury codes (E800–E929), available from the US Center for Disease Control and Prevention (CDC), was used (CDC, 2013). The main causes in this cohort are classified according to the matrix of E-code groupings for mortality due to injury and morbidity data (CDC, 2011). The top 3 injury diagnoses in this cohort were motor vehicle-related injury (E810-E829) (28.9%), suffocation (E911-E913) (22.0%) and drowning (E830, E832, E910) (21.6%).

Socioeconomic variables

As we were interested in a small-area analysis, we included all townships and small cities in Taiwan (n=349). To characterize township-level socioeconomic conditions, we first identified information from Taiwan's census statistics depicting neighbourhood and household economic conditions. We included variables with known socioeconomic differences within townships, such as per capita income, education and employment as well as the SES of the households with respect to employment and marital status including family structure (single, two-parent or grandparent home). We excluded redundant variables by looking closely at how correlated they were. Two variables with Pearson correlation coefficients ranging from 0.8 to 1.0 were excluded from further analysis. This overall selection process resulted in nine township-level variables that differentiated the residences under study in a useful way (Table 1). Next, we analysed these variables using exploratory factor analysis for the principal component using varimax with Kaiser normalization method (Pearson, 1901). The level of Kaiser-Meyer-Olkin measure of sampling adequacy was 0.639 indicating a significant difference by the Bartlett sphericity test ($P \leq 0.001$) (Cerny *et al*., 1977). The pattern matrix of the four most important factors found are shown in Table 2 (together explaining 82.5% of the variance) with the variables contributing most to the formation of each factor (loading >0.60) in bold. Each factor emphasized var-

Table 1. Definition of the nine socioeconomic factors used in the study.

Factor (type of expression)	Description
Per capita income ($)	Total income divided by the township population.
Divorced with household headed by female (%)	The divorced female household population divided by the total household population
Single-parent household (%)	The number of single-parent families divided by the total number of families
Household headed by grandparent(s) (%)	The number of grandparents rearing families divided by the total number of families
Population without high-school degree (%)	The population above 15 years of age with elementary school education or lower, divided by the total population above 15
Employment in agriculture (%)	The population with agricultural employment divided by the total population
Household without income (%)	The number of unemployed households divided by the total population
Unemployed males (%)	The number of unemployed males above 15 years old as a percentage of the male labour force
Unemployed females (%)	The number of unemployed females above 15 years old a percentage of the female labour force

Data source: Directorate-General of Budget, Accounting and Statics, Taiwan.

ious types of regional disparity as follows: i) Township-level poverty underlining the socioeconomic disadvantages of residency; ii) family burden representing limited family resources/support and family difficulties; iii) family fragility reflecting a broken family structure that is either single-parent family or family led by grandparents; iv) variables representing the township-level employment rate.

Cluster mapping

The SPSS v. 20 software statistical software package (SPSS Inc., Chicago, IL, USA) was used to analyse the injury mortality data and factor analysis. The annual age-specific mortality rates per 100,000 were calculated for the period 2000-2007 using age-specific population data from the 2004 census as denominator and adjusted by age standardization of the population data (Ahmad *et al*., 2001). To reduce undue large variations resulting from the collection of data from regions with small populations, empirical Bayesian smoothing was applied to the computed raw rates (Clayton and Kaldor, 1987). To identify clustering in all-cause and specific-cause mortality rates, the local indicator of spatial autocorrelation (LISA) and Moran's *I* with an empirical Bayes smoother were applied. This approach was used to identify hotspots, *i.e*. areas with high rates surrounded by areas with high rates (HH) and also cold spots, *i.e*. areas with low rate surrounded by areas with low rates (LL). Global Moran's *I* statistics was applied to measure spatial autocorrelations across the study. Negative (positive) values indicate negative (positive) spatial autocorrelation and values range from -1 (indicating perfect dispersion) to +1 (perfect correlation). Positive autocorrelation indicates that points with similar attribute values are closely distributed in space whereas negative spatial autocorrelation indicates that closely associated points are dissimilar. P-values<0.05 were considered significant and the number of permutations was set to 999.

Association between area-level socioeconomic status and child mortality

To determine the association between SES and child mortality at due to unintentional injury the local level, we first employed ordinary least square (OLS) models and tested the residuals for spatial autocorrelation using Global Moran's *I*. Because Global Moran's *I* values for the residuals were significant at $P \leq 0.001$, it spatial lag regression modelling was used to explicitly test the relationship between SES and mortality with regard to injury while controlling for spatial clustering (Brunsdon *et al*., 1998). We used OpenGeoda 1.12.1 software (Center for Spatial Data Science, University of Chicago, IL, USA) to carry out all these geospatial analyses and producing choropleth maps in ArcGis 10.2 (ESRI, Redlands, CA, USA).

Results

For the period 2000-2007, a total of 2,377 children aged 0-9 years, who had died from unintentional injury, were identified. The average age-specific, annual mortality rate was 10.76 per 100,000 children. The minimum, annual township incidence rate was 0.0 and the maximum 147.92, which is quite an enormous difference. An illustration of the uneven distribution of these deaths across townships can be seen in Figure 1A, which presents the average annual mortality rate due to unintentional injury. The results of cluster analysis (Figure 1B) reinforce this impression. The Moran's *I* of these accumulated deaths was 0.3794, which has a high statistical significance ($P \leq 0.01$).

Spatial clusters

When the accumulated spatial clustering (Figure 1B) was instead presented on an annual basis (Appendix Figure A1), large variations of both hotspots and cold spots can be seen. Although the hotspots were not the same, they tended to overlap and commonly include the counties Nantou, Hualien and Hsinchu. Using the LISA approach to analyze the high mortality regions and neighbouring areas, we found 36 HH regions located in the central mountains and eastern regions of Taiwan. The coldspots, a total of 43 LL regions, were primarily seen in the cities. The rate of deaths due to unintentional injury in the townships were thus correlated suggesting an underlying socioeconomic condition. For the youngest children, the clusters of deaths due to unintentional injury were statistically significant with the male subgroup (Figure 2A, C) showing spatial clusters in areas similar to those seen in the female subgroup. These findings were observed in central part of Taiwan. In the male group, the value of Moran's *I* was 0.2781 ($P \leq 0.01$) and 26 HH regions were identified with significant spatial clustering. In the female group, the value of Moran's *I* was 0.2162 ($P \leq 0.01$), and 23 HH regions were identified, also with significant spatial clustering. In the older children, only the male subgroup presented a spatial cluster (Moran's $I = 0.1430$, $P \leq 0.01$) with

Table 2. Pattern matrix from factor analysis.

Factor (type of expression)	Regional poverty	Family burden	Family fragility	Regional unemployment
Per capita income ($)	0.902	0.036	-0.066	-0.159
Divorced, household headed by female (%)	-0.535	-0.085	0.778	0.047
Single-parent household (%)	0.201	0.164	0.931	0.061
Household headed by grandparent(s) (%)	0.440	0.728	0.036	-0.033
Population without high-school degree (%)	0.864	0.380	-0.119	-0.077
Employment in agriculture (%)	-0.881	-0.003	-0.090	0.028
Household without income (%)	-0.052	0.913	0.079	0.088
Male unemployed population (%)	0.021	-0.050	0.075	0.866
Female unemployed population (%)	-0.203	0.117	0.005	0.810
Explained variability (%)	32.230	17.325	16.807	16.151

19 HH regions (Figure 2B). The central mountains and eastern regions were again included in these areas. In the female group, there was no spatial cluster but 6 HH regions were identified (Figure 2D).

Role of traffic accidents

Moran's *I* of the rate of deaths due to traffic accidents between 2000 and 2007 was 0.189 with a statistical significance of $P \leq 0.05$. LISA analysis showed 20 HH regions (Figure 3A). Age and gender factors were analysed and a spatial clustering found in the 0-4-year age group but not in the 5-9-year age group (Appendix Figure A2A-D).

Role of drowning

Moran's *I* of the rate of death through drowning between 2000 and 2007 was 0.3391, which indicates a statistical significance at $P \leq 0.01$. LISA analysis showed 27 HH regions (Figure 3B). Age and gender factors were analysed, and spatial clustering was found in the 0-4-year age group but not in the 5-9-year age group (Appendix Figure A2E-H).

Role of suffocation

Moran's *I* of the rate of death through suffocation between 2000 and 2007 was 0.1164, which indicates statistical significance and LISA analysis showed 13 HH regions (Figure 3C). Age and gender factors were analysed and spatial clustering was found in the male group aged 0-4 years and in the female group aged 5-9 years (Appendix Figure A2I-L).

Township-level socioeconomic status components

The township-level poverty component showed a very strong spatial clustering and the value of Moran's *I* was 0.7400 ($P \leq 0.01$) (Figure 4A). Moran's *I* of family burden component was 0.4304 ($P \leq 0.01$) and LISA analysis showed HH areas located in the North-east and on the eastern coast of the island (Figure 4B). Moran's *I* of family fragility component was 0.5621 ($P \leq 0.01$) and the HH areas concentrated in the East, the south-eastern coast and the central part of island (Figure 4C). It was not any spatial clustering with regard to regional unemployment and Moran's *I* was 0.0529 ($P \geq 0.05$) (Figure 4D).

Regression analysis

Four SES components (regional poverty, family fragility, family burden and regional unemployment) were found to be significantly related to death due to unintentional injury (Table 2). The most significant factor was township-level poverty (beta coefficient = 0.419). However, Moran's *I* of the residuals was 0.2304 ($P \leq 0.01$) suggesting that further spatial lag model is warranted due to the effect of spatial autocorrelation. An analysis of all deaths due to unintentional injury by the spatial lag model, the four components remained significant but the beta coefficient decreased and the spatial autocorrelation Rho (ρ) was 0.377 (statistically significant at $P \leq 0.01$), while R^2 ranged from 0.285 to 0.375 indicating that these deaths were associated with spatial neighbouring effects For deaths due to traffic accidents, poverty rate and family fragility were the significant factors (Table 2). Moran's *I* of the residuals was 0.0917 ($P \leq 0.01$), while the spatial lag model showed a Rho of

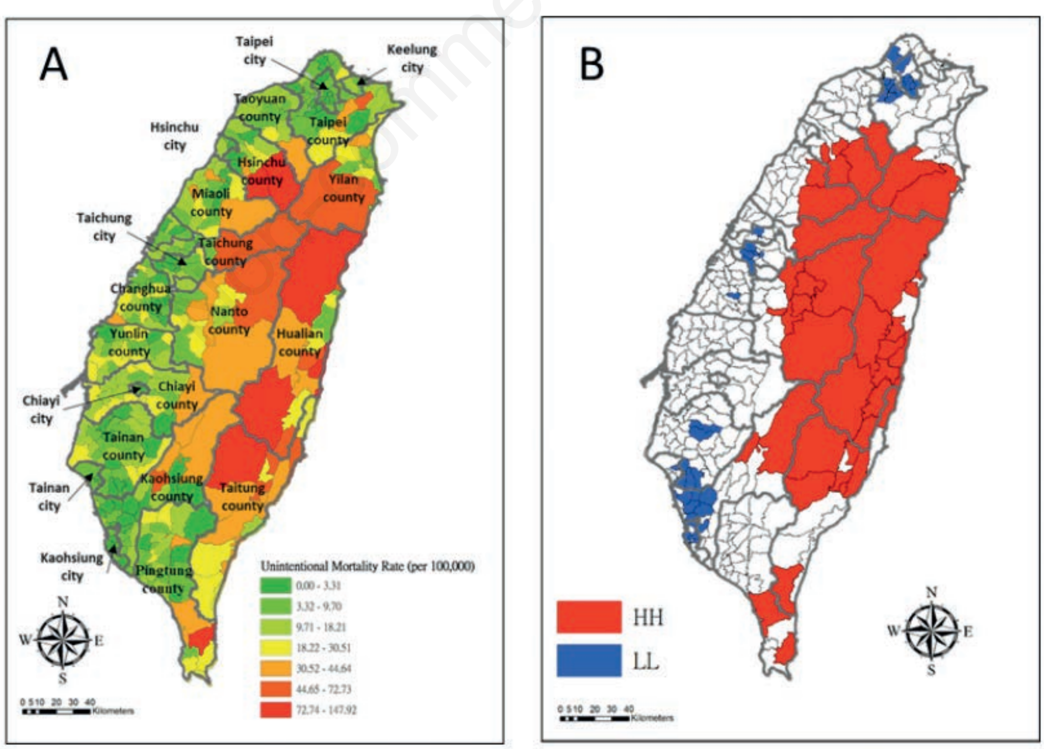

Figure 1. Average rate of annual mortality due to unintentional injury among children age 0-9 years across 349 regions (townships and cities) in Taiwan during 2000-2007. (A) Mortality rate per 100,000 population; (B) Cluster graph showing hotspots (red) and cold spots (blue). HH, high rates; LL, low rates.

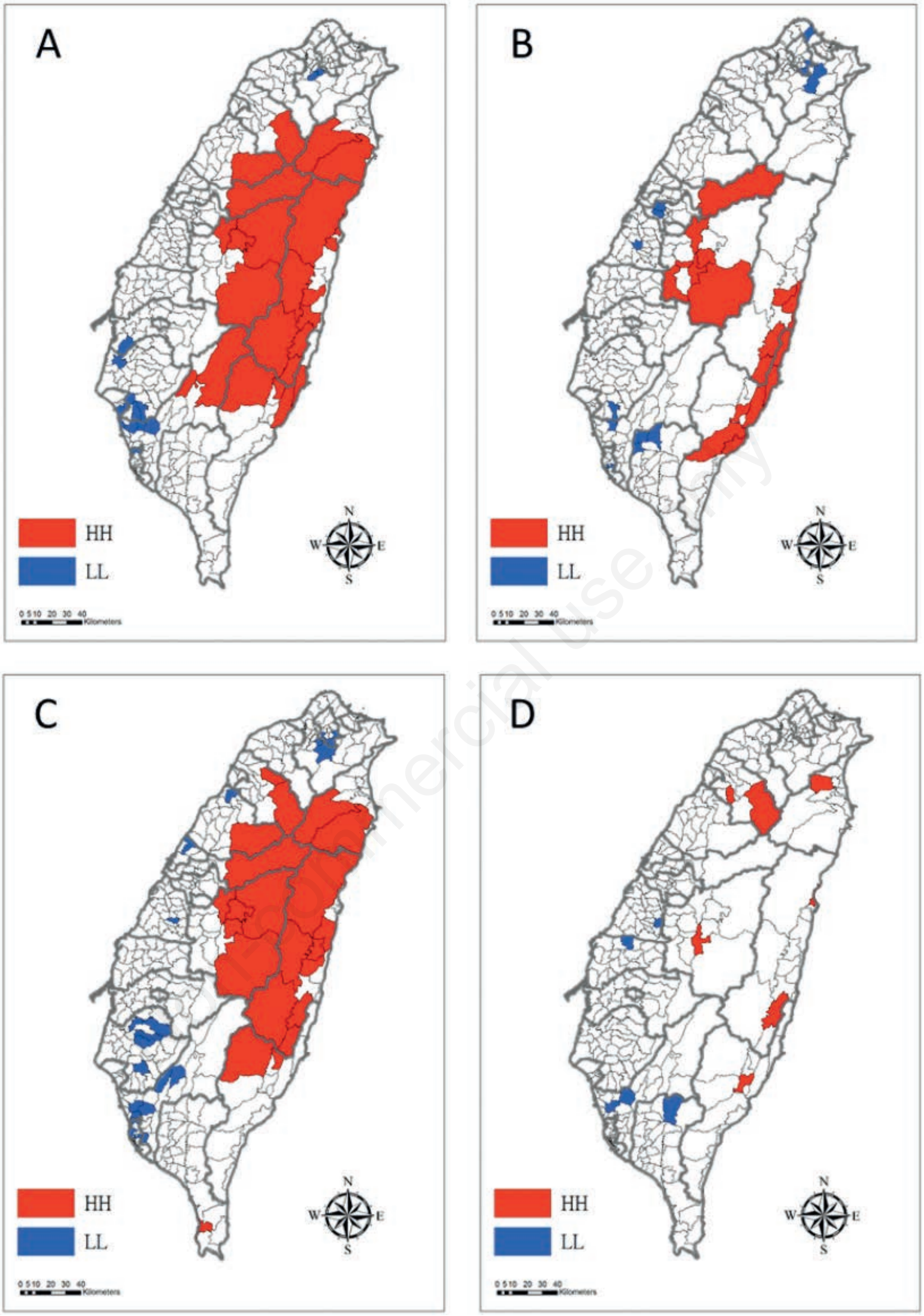

Figure 2. Cluster graph of childhood deaths due to unintentional injury by age and gender in 2000-2007. (A) Results for males 0-4 years of age; (B) Results for females 0-4 years of age; (C) Results for males 5-9 years of age; (D) Results for females 5-9 years of age. HH, high rates; LL, low rates.

0.157 indicating statistical significance and the R^2 ranged from 0.159 to 0.182. Although these deaths were influenced by spatial clustering, the effect was small. All four SES components were significantly related to death due to drowning (Tables 3 and 4). The most significant factor was poverty (beta coefficient = 0.397). Moran's I of the residuals was 0.1607 ($P \leq 0.01$) and the spatial lag model showed Rho to be 0.332 indicating statistical significance ($P \leq 0.01$), while R^2 ranged from 0.233 to 0.304 indicating that these deaths were influenced by spatial and neighbouring effects For death due to suffocation, poverty rate and family fragility were the significant factors (Table 2). Moran's I of the residual value was 0.1041 ($P \leq 0.01$) and the spatial lag model showed Rho level as 0.186 indicating statistical significance ($P \leq 0.01$), while R^2 ranged from 0.047 to 0.076. Although these deaths were influenced by spatial effects, the effect was small.

Discussion

The study highlights the relationship between different area-level socioeconomic indicators and unintentional injury mortality rates in Taiwan. These rates appeared to be significantly modified by sociodemographic factors. We found that drowning was more common near the east coast than anywhere else, while deaths due to traffic were common in the central mountainous area. The study showed that local socioeconomic environments influence the mechanism that can leads to injury-related deaths. Additionally, regional clusters in central and eastern Taiwan were noted in the lowest age groups (0-4-years old), significantly so in males. Children living in deprived areas under disorganized family conditions constitute vulnerable subgroups whose needs should be considered in future policies. Immediate attention is called for.

Death due to unintentional injury is often influenced by place of residence and parental occupation. Using linear regression analysis, Durkin *et al*. (1994) report that childhood unintentional injury in northern Manhattan NY, USA from 1983 to 1991 is significantly related to family income, single parent household and male unemployment. In addition, incomplete family structure, such as households headed by grandparents is also an important factor (Bishai *et al*., 2008). Children living in rural areas show a higher mortality rate than those living in townships or cities and this effect lasts until the child reaches 15 years of age (Hu *et al*., 2010). Analysing socioeconomic parameters, Nolasco *et al.* (2009) found that unemployment and low education are associated with higher traffic accidents in adolescents. In South Korea, a cohort study concluded that deaths due to unintentional injury in children <8 years old is associated with life in rural areas, parents with a low level of education and parental occupation (Hong *et al*., 2010). In concurrence, our study found socioeconomic components, including poverty, economic burdens and fragility as well as unemployment, to be significantly associated with children's deaths due to unintentional injury

Flower *et al*. (2006) conducted an analysis of agricultural areas in the US, including Iowa and North Carolina from 1973 to 1998 reporting that although the overall mortality rate did not increase, the number of deaths related to agricultural machines had increased (odds ratio = 3.93). Their study suggests that different area-level socioeconomic components should be taken into account even though overall mortality remained stable. It highlights the importance of the geographical environment as the possible determinants of mortality due to unintentional injury.

This study has some limitations, *e.g.*, the number of partici-

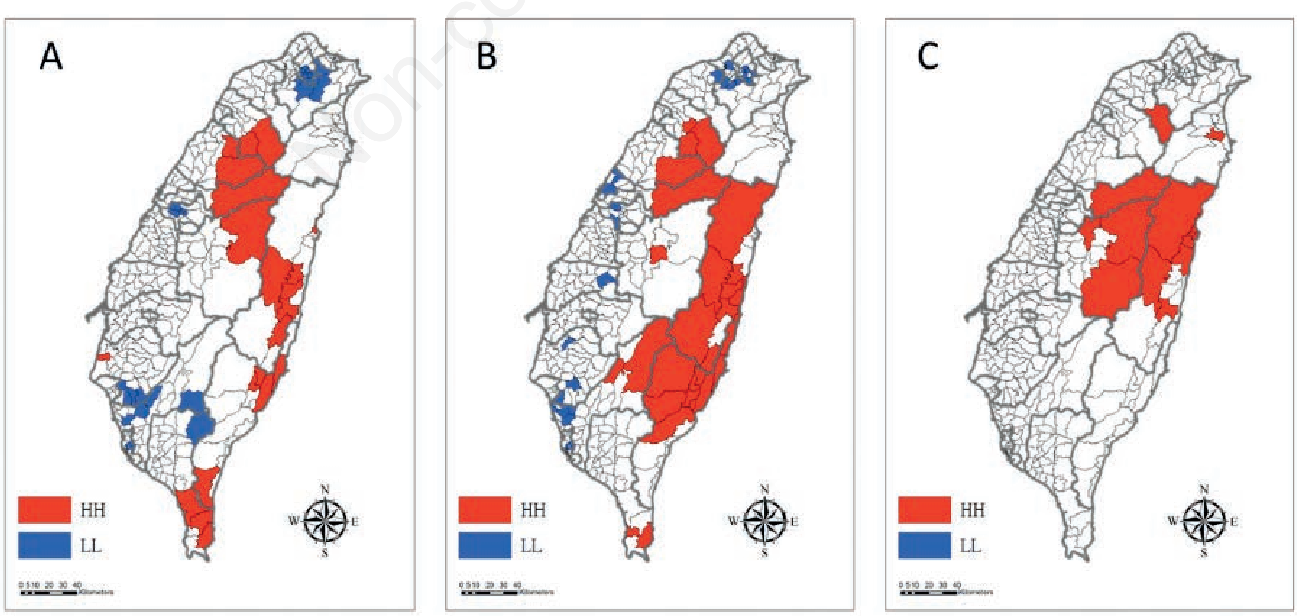

Figure 3. Cluster graph of childhood unintentional injury death by type 2000-2007. (A) Traffic accidents; (B) Drowning; (C) Suffocation. HH, high rates; LL, low rates.

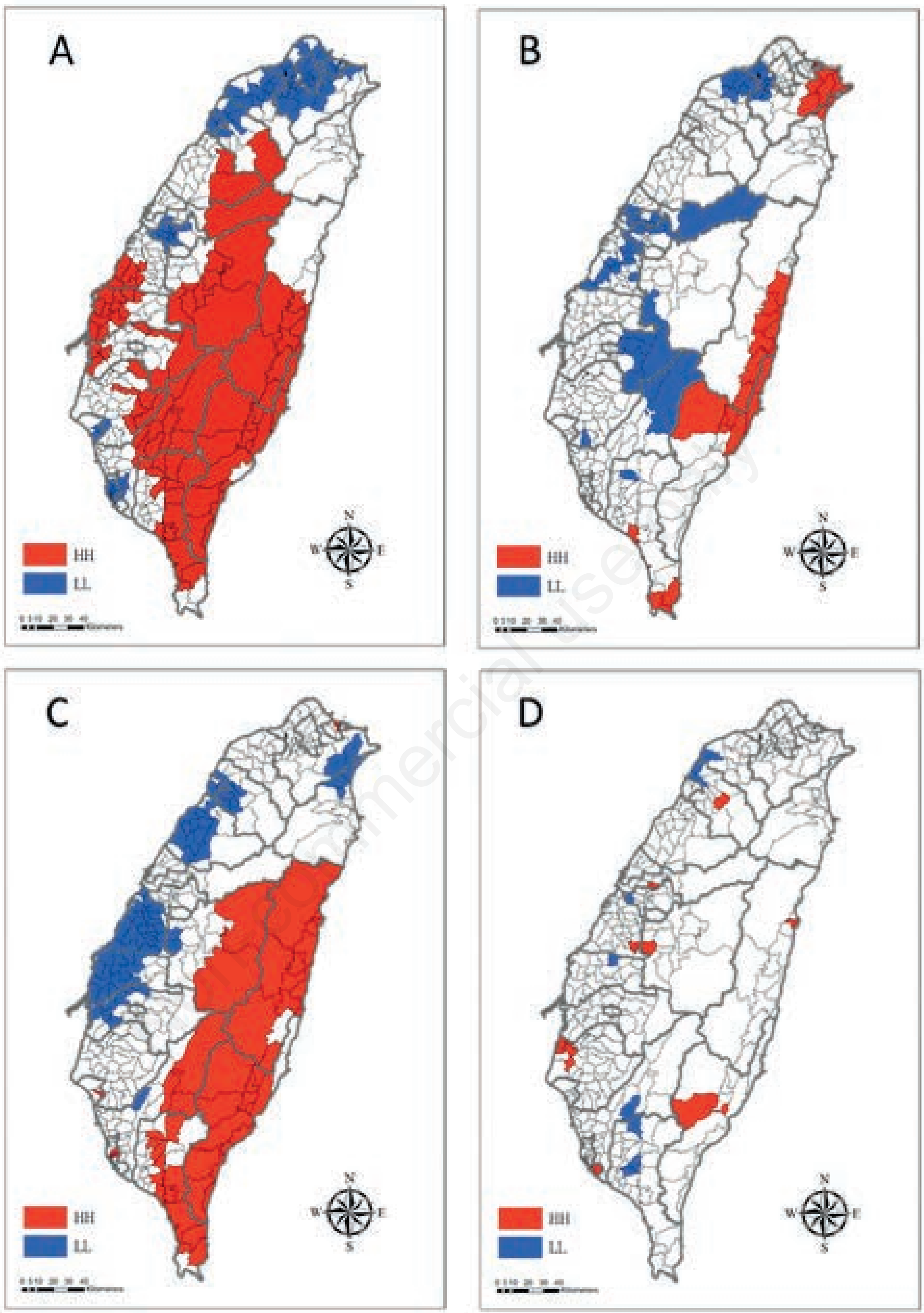

Figure 4. The clustering of four socioeconomic concepts using LISA analysis. (A) With regard to the poverty component, 92 high rates (HH) regions and 85 low rates (LL) regions were identified; (B) With regard to the family burden component, 26 HH regions and 48 LL regions were identified; (C) With regard to the family fragility component, 52 HH regions and 72 LL regions were identified; (D) With regard to the unemployment component, 11 HH regions and 9 LL regions were identified.

Table 3. Regression analysis of childhood deaths due to drowning and suffocation 2000-2007.

Variable	Ordinary Least Square model Coefficient	SE	Spatial lag model Coefficient	SE
Drowning				
Regional poverty	0.397***	0.046	0.289***	0.050
Family burden	0.169***	0.046	0.100**	0.045
Family fragility	0.214***	0.046	0.160***	0.046
Regional unemployment	0.094**	0.046	0.086	0.044
Rho (ρ) level			0.332***	
Adjusted R^2	0.233		0.304	
Akaike information criterion	902.685		882.803	
Schwarz criterion	921.961		905.934	
Residual value of Moran's *I*	0.1607**			
Suffocation				
Regional poverty	0.197***	0.052	0.177***	0.053
Family burden	0.050	0.052	0.035	0.051
Family fragility	0.116*	0.052	0.106**	0.051
Regional unemployment	0.030	0.052	0.027	0.051
Rho (ρ) level			0.186**	
Adjusted R^2	0.047		0.076	
Akaike information criterion	979.437		972.444	
Schwarz criterion	998.713		987.864	
Residual value of Moran's *I*	0.1041*			

SE, standard error; *P-value<0.05; **P-value<0.01; ***P-value≤0.001.

Table 4. Regression analysis of total childhood deaths due to unintentional injury and those due to traffic accidents 2000-2007.

Variable	Ordinary Least Square model Coefficient	SE	Spatial lag model Coefficient	SE
All types of injury				
Regional poverty	0.419***	0.045	0.302***	0.048
Family burden	0.188***	0.045	0.104**	0.043
Family fragility	0.230***	0.045	0.171***	0.044
Regional unemployment	0.171***	0.045	0.156***	0.042
Rho (ρ) level			0.377***	
Adjusted R^2	0.285		0.375	
Akaike information criterion	878.426		847.372	
Schwarz criterion	897.701		870.502	
Residual value of Moran's *I*	0.2304**			
Traffic injury				
Regional poverty	0.360***	0.049	0.318***	0.053
Family burden	0.082	0.049	0.052	0.048
Family fragility	0.157***	0.049	0.140***	0.049
Regional unemployment	0.088	0.049	0.082	0.048
Rho (ρ) level			0.157**	
Adjusted R^2	0.159		0.182	
Akaike information criterion	934.753		931.81	
Schwarz criterion	954.029		948.23	
Residual value of Moran's *I*	0.0917*			

SE, standard error; *P-value<0.05; **P-value<0.01; ***P-value≤0.001.

pants and structure were different between the years investigated, and therefore the distribution childhood deaths due to unintentional injury also varied (Appendix Figure A1). We tried to provide a thorough trend of the spatial cluster analysis by using accumulative data on and performing a spatial lag regression evaluation. Although the population structure changed over time, up to 94.6% of those in residence stayed in the same county and township according to the health insurance database and population dynamics survey file. Indeed, the limitation on the precise person-level information could be eliminated (Lin *et al*., 2011) by relying on area-level analysis. In addition, we could not cover all socioeconomic variables. For example, although parental age and foreign parents were not included in our study, multiple socioeconomic factors were considered. Nine socioeconomic variables were settled into four major components with 83.24% variability using the Kaiser-Meyer-Olkin measure. Nevertheless, other social factors, such as social atmosphere and culture, cannot be quantified. We used both step-by-step regression and spatial lag models to evaluate the association between socioeconomic disadvantages and deaths due to unintentional injury. Furthermore, the hotspots were identified to increase public awareness regarding the parts of the country needing more economic and social support to avoid preventable deaths.

Conclusions

Unintentional injury is a major cause of death in children in Taiwan and elsewhere. This study provides evidence by further examining the association between socioeconomic factors and deaths based on spatial, neighbouring effects. Significant associations were found between death due to unintentional injury and social disadvantages including local poverty situations, family fragility, family burden and unemployment while controlling for spatial autocorrelation. The results presented here can be used to target and improve neighbourhoods with geographic inequalities that have led to high child mortality due to unintentional injury.

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