Geographical Inequalities in Alcohol-Related Mortality Rates in Taiwan due to Socio-Demographic Differences

Chen-Mao Liao¹ and Chih-Ming Lin²,*

¹Department of Applied Statistics and Information Science, Ming Chuan University, Taoyuan, Taiwan, and
²Department of Healthcare Information and Management, Ming Chuan University, Taoyuan, Taiwan

*Corresponding author: No. 5, Teh-Ming Rd., Gwei-Shan, Taoyuan County, 333, Taoyuan, Taiwan. Tel.: +886-3-350-7001; Fax: +886-3-3593880; E-mail: cmlin@mail.mcu.edu.tw

Received 28 November 2014; Revised 18 March 2015; Accepted 24 March 2015

Abstract
Aims: To assess the relationships between alcohol-related mortality and socio-demography in Taiwan.

Methods: Using 2002–2006 data from the national death-diagnosis registration system, we calculated the alcohol-attributed disease mortality of those aged 15 and older in 348 townships in Taiwan. This study provides spatial clustering of alcohol-attributed disease mortality rates and area socio-demographic conditions across townships, examining the relationship between the two using a spatial autoregressive model.

Results: The relative risk of death due to alcohol-attributed diseases was estimated to increase by 2.1 and 0.9% as a result of a 1% increase in the percentage of men and aboriginal residents, respectively. The risk of death was estimated to decrease by 25% for every 1 year increase in education level. Industrialization and labor participation were also found to be predictors of the outcome measure in areas with differing levels of urbanization.

Conclusions: This study provides significant evidence that township-level relationships between alcohol-related mortality and socioeconomic variables exist in Taiwan. Public health policymakers should better prioritize the specific areas in which comprehensive intervention should be undertaken accordingly.

INTRODUCTION

In most parts of the world, the health burdens (morbidity, mortality and disability) related to alcohol consumption are substantial. The WHO has estimated that the use of alcohol leads to ∼3.7% of total global mortality and is responsible for 4.4% of the global burden of disease (The Lancet, 2009). A systematic review estimated that alcohol consumption was responsible for 31,000 deaths in the UK in 2005 and cost the UK National Health Service 3.0 billion pounds (Balakrishnan et al., 2009). In the USA, ∼85,000 deaths per year are associated with drinking, including unintentional or intentional injuries and a range of diseases. 2.3 million years of potential life lost (YPLLs), or ∼30 years of life lost on average per death, have been attributed to excessive alcohol use. 35% of those YPLLs resulted from chronic conditions such as liver disease (Centers for Disease Control and Prevention, 2004). The alcohol-associated disease burden is closely related to the average volume of alcohol consumption, and the disease burden is heaviest among the poor and those who are marginalized by society (Rehm et al., 2009).

It is thought that certain sub-groups of the population may experience greater levels of alcohol-related mortality, including socio-economically disadvantaged individuals (Harrison and Gardiner, 1999; Martikainen et al., 2003; Breakwell et al., 2007; Erskine et al., 2010; Connolly et al., 2011; Mulia and Karriker-Jaffe, 2012). Some multilevel studies have demonstrated an effect of area or neighborhood characteristics on alcohol-related mortality independent of individual-level confounders (Martikainen et al., 2003; Blomgren
The relationship between socioeconomic environments and their geographical locations has long been used to examine inequalities in health. A better understanding of the spatial factors that reduce alcohol-related issues may help health policy makers to set priorities and to make appropriate interventions available to vulnerable populations. Studies of different populations have observed a greater risk of dying from an alcohol-related cause in urban areas (Makela, 1999; Erskine et al., 2010; Connolly et al., 2011). Using a spatial approach, Berke et al. (2010) examined demographic differences in alcohol retail density and concluded that the density of alcohol retailers was associated with poverty and race. A Scottish study used a geographical analysis and found gender differences in alcohol-related mortality (Emslie and Mitchell, 2009). Nonetheless, only a limited number of studies exploring the relationships between alcohol-related mortality and socio-demography using techniques from spatial statistics have been published. In addition, previous studies that have indicated an association between alcohol-related issues and socioeconomics were mostly conducted in Western societies, and whether those findings can be generalized to populations which have different racial make-ups, cultural traditions or health-care systems is a question worth exploring further. Moreover, the differences in socioeconomics due to urbanization may result in residual confounding by the spatial variable in analyzing the relationships between socioeconomics and mortality. Investigating this relationship in terms of urban and rural areas can elucidate the potential risk factors in different developed areas and help policy makers to provide localized policies.

In Taiwan, clinical histology has shown that the alcohol-related disorders affecting different populations were primarily alcoholic cirrhosis, alcoholic hepatitis, and various severity levels of fatty metamorphosis (Liu et al., 1998). One national survey previously reported that the alcohol consumption prevalence rates for men and women aged 12–64 years in 2005 were 54.8 and 22.1%, respectively (Nation Health Research Institute, 2005). Socioeconomic development has led to a progressive increase of alcohol consumption in Taiwan, with an accompanying increase in alcohol-related psychiatric problems and liver disease. Similar to most Asian countries, Taiwanese alcohol consumption differs from that in Western nations. Mainly due to culinary traditions and cultures, domestic rice spirits have always been more popular than other alcoholic beverages (e.g. wine and scotch). In this paper, we apply spatial autoregressive models to estimate how demographic conditions and socioeconomic characteristics influence alcohol-related mortality in an Asian national context.

MATERIALS AND METHODS

Study area and spatial unit

We used an ecological (geographical) study design for our investigation. Specifically, we sought out regions that were physically small enough to reflect spatial variations in mortality rates across Taiwan but large enough in terms of population to provide robust ADM estimates. The township level was used as the spatial unit of analysis for investigating geographical inequalities in mortality and socioeconomic conditions. Moreover, in the master plans formulated by policy makers in Taiwan, including health-care resource plans, medical emergency zoning plans, and governmental budget allocation projects, the township is the basic unit of government that is addressed. Each township has 3700–60,000 households. There are 359 townships across Taiwan, but in order to conduct a conditional spatial autoregressive analysis, 11 islands or otherwise isolated townships were excluded from this study because they did not have neighboring areas. So, data for 348 townships of different urbanization levels measuring from 8–120 square kilometers in size and with an average population of 62,543 (0.1–20.7 thousand people per square kilometer) were ultimately collected.

Mortality data from 2002 to 2006 were retrieved from Taiwan’s Death Registry (TDR). In Taiwan, causes of death are determined by the physicians who provided treatment or care to the decedent, and the death certificates are then confirmed by a coroner or pathologist. The following information regarding each decedent was obtained from death certificates: sex, age at death, cause of death, place of death and residential district (name and code of township). Alcohol-related diseases were defined based on comprehensive reviews of the literature (Rehm et al., 2006; Wagenaar et al., 2009). For chronic diseases, risk relations were taken from the published literature and combined with exposure to calculate age- and sex-specific alcohol-attributable fractions (AAFs). Alcohol-caused mortality represents all deaths caused by diseases for which the AAF is 1.0. Rather than emphasizing the analysis of other alcohol-related causes of death, we emphasized alcohol-attributed disease mortality (ADM, e.g. AAF = 1) as the end-point of this study in order to best reflect the direct influence posed by socioeconomic conditions. Deaths were classified according to the 9th edition of the International Classification of Diseases (ICD). In addition, data regarding individuals who were 15 years old and older who died from alcohol-attributed diseases, including alcoholic liver disease (ICD code = 571.0–571.3), alcohol psychoses (291.0–291.9), alcohol abuse (303), alcohol dependence syndrome (305.0), alcoholic polyneuropathy (357.5), alcoholic cardiomyopathy (425.5), alcoholic gastritis (535.3) and acute alcohol poisoning (980.0), were collected and aggregated into township-level data, which were stratified by age group for the whole study area. In total, there were 20,990 males and 9679 females who died during the study period and whose underlyings causes of death were attributed to one of the above forms of ADM. Given that our data consist of publicly available area-level data, ethical approval was not needed for this study.

Mortality rates and area-level variables

The annual mortality data were aggregated; the average number of deaths in the 5-year period was used as the numerator, and the household population obtained from Taiwan’s household registrations was used as the denominator. The mortality data of the period were then grouped to match the age structure of the household data, after which we calculated the raw ADM rate for each township. We then produced the direct, age-standardized mortality rate for ADM based on the WHO’s world standard age-specific population (Ahmad et al., 2000). There are no official deprivation indices available in Taiwan. Appropriate geographic variations in population demographics and socioeconomic conditions, however, can be captured at the township level. The socio-demographic variables were selected according to past studies. In addition, the possibility that access to health-care services might reduce mortality due to alcoholic diseases should also be noted. The detection of such differences is an important issue for health policy planners when designing programs for the provision of health-care services for the whole population. We used three registration datasets from the year 2000 that had been assembled by the Ministry of Interior (MOI), the Committee of Aboriginal Affairs, and the Department of Health as a survey of demographic and socioeconomic statuses. These nationwide datasets included a measure of the demographic and socioeconomic structures at the area level. Specifically, this measure is a combination of three township-level demographic variables — population density, sex ratio, and the percentage of aboriginal residents — and seven socioeconomic variables, namely, average years of
education, the proportion of residents who are married or living with family, the home ownership rate, the proportion of industry, the labor force participation rate, the annual median household income, and the density of medical practitioners. All the area variables were measured as continuous variables. Moreover, to investigate the differences due to urbanization, for example, those due to differences in the number of people employed in different sectors or to the differing structures of local economies, we used the national harmonized classification system for urban and rural areas (categories based on densely and thinly populated areas) in Taiwan developed and defined by the Office for National Statistics, MOI.

Statistics analyses
We calculated the ADM rate to examine the effects of socio-demographic variables in graphical terms. The Global Moran’s I statistic was used as a descriptive measure of overall spatial clustering of both the dependent and independent variables. In essence, the higher the value of Moran’s I, the higher the indication of clustering of similar values. Getis and Ord’s local spatial statistic $G_i^*(d)$ was used to determine local ADM clustering; the method and results can be found in a recent analysis (Lin and Wen, 2012). In addition, we used spatial regression models to examine the relationships between the ADM rate and the independent variables. After stratification according to urban-rural status, the demographic data and socioeconomic variables were entered into the spatial models. The normality assumption of residuals was confirmed by the Lilliefors test. The maximum pseudo-likelihood estimation (Anselin, 1988; LeSage, 1999) led to substantively similar parameter estimates and 95% confidence intervals. The basic spatial lag model was assessed first. The model’s intercept dependent variable ADM rate was lagged across neighbors. The next model, the spatial Durbin model, modifies the spatial lag model in an attempt to model the spatial heterogeneity of the data by introducing lagged predictor variables into the model. This model specification better described the spatial data generating process assumed in the error model, where we were basically modeling missing spatial covariates. Lagrange multiplier statistics (LM) were used to aid in model specification (Chi and Zhu, 2008). This was done to assess which model was most appropriate for the specified outcome variable and substantive model. The LM tests suggested that both the Durbin model and error model fit this model specification appropriately. Moreover, the error model was nested in the Durbin model and likelihood ratio test values showed that both model specifications were undifferentiated. Given its good variation explanation ($R^2 = 0.765$), the spatial error model was selected as the final model. The error model is defined by the following equations:

$$y = X\beta + \epsilon$$
$$\epsilon = \rho We + \epsilon$$

We took the logarithmic transformation for the skewed ADM data, letting y be the logarithm of ADM. X is the matrix of independent variables. $\beta$ is the vector of the estimated coefficient for the X variables. The exponentiated $\beta$ represents the ‘mortality risk ratios,’ with those in the reference group having a mortality risk ratio of 1. The mortality risk ratio has a straightforward percentage interpretation; for example, a group with a ratio of 1.25 has a 25% higher mortality than the reference group. $\epsilon$ is the model’s residual. $\epsilon$ is an error term, W is a matrix of row standardized spatial weights. The weight matrix accounts for the total number of neighbors that a township has, and it assigns a value of 1 whenever two townships are neighbors, and 0 otherwise (Bivand et al., 2013). $\rho$ is the spatial autoregressive parameter which reflects the spatial dependence inherent in our sample data, measuring the average influence on townships by their neighboring townships (Anselin and Bera, 1998). The value of $\rho$ is bounded between −1 and 1. When $\rho$ is zero, the spatial model collapses to the prototypical regression model. The correlation coefficient and variance inflation factor were used to measure collinearity in the regression analysis. Finally, the income variable was excluded because it explained less of the variation in the model than the education variable. Version 2.14.1 (Institute for Statistics and Mathematics, 2011) was used to perform the spatial modeling. The spdep package (Bivand et al., 2013) was also used through R as part of the spatial analysis.

RESULTS
The spatial distributions of the standardized mortality rates in 2002–2006 were generated. The areas that had higher alcohol disease mortality rates (127–235 deaths per 100,000 people) are located in eastern and central Taiwan, regions which consist mostly of mountainous areas. In northern Taiwan, which contains the most populous areas, the mortality rates were lower (<26 deaths per 100,000 people). Table 1 provides descriptive statistics for the socio-demographic

| Table 1. Township-level alcohol-attributed disease mortality (ADM) rates and socio-demographic variables in Taiwan |
|---------------------------------------------------------------|-------------------|-------------------|-------------------|
| Socio-demographic variables                                  | Whole state       | Rural townships   | Urban townships   |
| Count of townships                                            | Mean s.d.         | Mean s.d.         | Mean s.d.         |
| ADM (per 100,000 people)                                      | 36.64 30.09       | 42.92 33.58       | 26.37 19.42       |
| Population density (per km²)                                  | 2707.19 5744.55   | 777.76 1984.38    | 5902.80 8064.57   |
| Male (%)                                                      | 52.22 2.27        | 52.73 2.20        | 51.41 2.14        |
| Aborigine (%)                                                 | 9.31 24.00        | 13.32 28.29       | 2.83 12.17        |
| Education (years)                                             | 8.73 0.86         | 8.36 0.61         | 9.32 0.88         |
| Married or living with family (%)                             | 46.44 3.35        | 47.12 3.60        | 45.35 2.54        |
| Home owner (%)                                               | 85.43 7.19        | 87.83 6.65        | 81.61 6.35        |
| Industry (%)                                                  | 28.56 13.00       | 26.98 12.07       | 31.13 14.05       |
| Labor participation (%)                                       | 67.95 5.61        | 69.24 5.82        | 65.87 4.55        |
| Medical practitioners (per 10,000 people)                     | 17.98 49.69       | 8.09 39.60        | 34.25 59.55       |
| Household income (in thousands of USD)                        | 16.9 2.06         | 15.33 1.45        | 17.33 2.29        |

s.d.: standard deviation.

* $P < 0.05$ by randomization based on 999 Monte Carlo replicates.
factors and mortality rates. Substantial geographical variation was observed for different urbanization levels. The standardized mortality rate in rural areas (42.9/100,000) was higher than the rate in urban areas (26.4/100,000). Compared with urban townships, rural townships had higher mean proportions of male residents (52.7 vs. 51.4%), aboriginal residents (13.3 vs. 2.8%), residents who were married or living with family (47.1 vs. 45.4%), home owners (87.8 vs. 81.6%) and labor participants (69.2 vs. 65.1%), whereas they had lower levels of education (8.4 years vs. 9.3 years), industrial rate (27.0 vs. 31.1%), medical practitioner density (8.1/10,000 vs. 34.3/10,000) and household income (15.3 thousand dollars vs. 17.3 thousand dollars). The table also presents the values for the global Moran’s I statistic for each variable. The statistical significance of all the Moran’s I values was judged based on Monte Carlo replicates. The Global Moran’s I statistic for the dependent variable was 0.52, which was a high positive value indicating clustering of ADM in the townships. All of these independent variables also showed significant spatial clustering.

The scatter plots for the ADM and each socio-demographic variable for the 348 townships are shown in Fig. 1. Of those, the proportions of male and aboriginal residents presented a positive trend for mortality rate. In contrast, the education years presented an inverse pattern.

The pseudo-R² of the spatial error model was 0.765, and the residual of the model was analyzed with a Lilliefors test and showed normality (D = 0.060, P = 0.178). Table 2 shows the results from the multivariable auto-regression model, which identified significant predictors for the ADM rate. After adjusting for potential confounders, there were no significant differences in ADM due to sex, the married or living with family, the home owner or medical practitioner density. Overall, the average influence exerted on townships by their neighboring townships was strong (ρ = 0.53). In addition, the spatial dependent parameter (ρ) for urban townships and rural townships was 0.44 and 0.42, respectively. Four of the predictors, namely, the sex ratio, the percentage of aboriginal residents, the average education level and the rate of industry, showed significant associations with the dependent variable. Townships in which the percentage of male or aboriginal residents was high had higher ADM risk. The relative risk of death due to alcohol-attributed diseases was estimated to increase by 2.1% (95% CI, 0.0–4.1%) and 0.9% (95% CI, 0.6–1.1%) as a result of a 1% increase in the percentage of men and aboriginal residents, respectively. The effect of the percentage of aboriginal residents in urban townships (1.7%; 95% CI, 1.1–2.3%) was stronger than in rural townships (1.0%; 95% CI, 0.7–1.2%). On the other hand, a significantly decreased relative risk of mortality with increasing education level was observed, irrespective of urbanization. The risk of death was estimated to decrease by 25.0% (95% CI, 18.9–31.6%) for every 1 year increase in education level among rural townships. The corresponding figure for education was a 16.2% (95% CI, 3.7–27.0%) decline in urban townships. Unlike in rural townships, a significant association between the ADM rate and the labor participation rate was observed in urban townships. The risk of death was decreased by 2.0% (95% CI, 0.6–3.4%) for every 1% increase in the labor participation rate. On the other hand, the risk of death was observed to decrease by 0.8% for every 1% increase in industrial proportion in rural areas.
Table 2. Socio-demographic factors associated with alcohol-attributed disease mortality (ADM) rates in Taiwan

<table>
<thead>
<tr>
<th>Socio-demographic variables</th>
<th>Whole state</th>
<th>Rural townships</th>
<th>Urban townships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1.020654</td>
<td>1.014887</td>
<td>1.035444</td>
</tr>
<tr>
<td>Aborigine</td>
<td>1.009261</td>
<td>1.009595</td>
<td>1.017197</td>
</tr>
<tr>
<td>Education</td>
<td>0.744949</td>
<td>0.740013</td>
<td>0.838295</td>
</tr>
<tr>
<td>Married or living with family</td>
<td>0.982920</td>
<td>0.986651</td>
<td>0.995430</td>
</tr>
<tr>
<td>Home owner</td>
<td>1.002484</td>
<td>0.995182</td>
<td>1.011179</td>
</tr>
<tr>
<td>Industry</td>
<td>0.993300</td>
<td>0.991890</td>
<td>1.001731</td>
</tr>
<tr>
<td>Labor participation</td>
<td>0.994687</td>
<td>0.998631</td>
<td>0.979908</td>
</tr>
<tr>
<td>Medical practitioner</td>
<td>0.999571</td>
<td>0.999220</td>
<td>1.000170</td>
</tr>
<tr>
<td>Spatial dependence ($\rho$)</td>
<td>0.522670</td>
<td>0.402679</td>
<td>0.343545</td>
</tr>
</tbody>
</table>

Pseudo $R^2$ = 0.765156

CI, confidence interval; $b$, coefficient; s.e., standard error.

Coefficients ($b$) have been exponentiated with the estimated coefficient ($\beta$) and adjusted for covariates (e.g., male, aborigine, education, married or living with family, home owner, industry, labor participation, medical practitioner and spatial dependence).

DISCUSSION

The results revealed that ADM and socio-demographic conditions in Taiwan are not randomly distributed across space. Our study has also shown that higher mortality among people living in socio-demographically disadvantaged areas can be observed in Asian societies. The area neighborhood characteristics, meanwhile, have independent effects on alcohol-related mortality in communities. Due to a strong and positive spatial autocorrelation with the ADM rate, the effect of neighborhood townships was considered as a confounder for the study. Our findings indicate that similar socio-demographic conditions may cause the ADM risk among townships, but the effect strength exhibited some differences between urban and rural areas. Blomgren et al. (2004) reported that a protective effect due to a high level of urbanization was revealed after adjustment for individual-level and area-level characteristics. In contrast, studies in different populations have also observed a greater risk of dying from an alcohol-related cause in urban areas (Makela, 1999; Singh and Hoyert, 2000; Erskine et al., 2010; Connolly et al., 2011). The variations in mortality among different geographical areas may reflect, then, that they are related to specific life or social circumstances.

The present study found that a higher percentage of aboriginal residents could raise the risk of alcoholic mortality in a community. Nine percent of the overall Taiwanese population of 23 million people are members of aboriginal ethnic groups. A recent study identified clusters of ADM in the areas where the aboriginal population is dominant; enhanced drinking prevention and control measures and efficient allocation of public health resources are thus required in these regions (Lin and Wen, 2012). In the USA, May and Gossage's (2001) investigation showed a 60% prevalence of adult drinking among Indians of the northern US states. Genetic and race differences between individuals experiencing different levels of deprivation have been proposed in relation to alcohol-related disorders (Jones-Webb et al., 1999; Makela, 1999). Previous studies of Taiwan have also indicated that the prevalence of alcohol drinking increases with age, is higher among aborigines than among persons of Chinese origin, and is higher among those with lower levels of education than among those with higher levels (Chen et al., 2001; Liang et al., 2004). As a specific cultural habit, the illegal distilling and consumption of rice spirits is popular among aboriginal tribes in Taiwan, and this practice may increase the risk of impure alcohol consumption, resulting in higher rates of ADM.

Deprivation would have a negative effect in terms of greater mortality due to drinking. Our results revealed a reverse correlation between alcoholic mortality and education level in a population. Moreover, a high labor participation rate in urban areas or a high proportion of industry in rural areas may result in an advantage in terms of alcohol-related mortality. Wojtyniak et al. (2005) have suggested that those of higher social status are better protected against health risks associated with drinking. Consistent with our findings, Rosicova et al. (2011) found the unemployment rate and low levels of education appeared to be important determinants of regional alcohol-related mortality. Blomgren et al. (2004) reported that high proportions of manual workers and unemployed individuals were found to produce adverse effects in terms of increasing alcohol-related mortality; in fact, the level of education may affect alcohol-related mortality more strongly than overall alcohol intake, particularly with regard to the acute consequences of drinking. There is always a reservoir of individuals in a population who are about to have an exacerbated health issue due to a chronic alcohol-related condition. It could be considered that high self-awareness or the provision of health information from the community may serve to prevent the exacerbation of adverse individual health problems, thereby reducing the number of deaths. Irrespective of drinking behavior, a high individual or neighborhood education level could have positive effects in terms of preventing dangerous alcohol-related health issues. Additionally, our results suggest that raising the labor participation rate in an urban area could protect a population from the most severe consequences of drinking.
Compared with rural townships, there are higher rates of industrialization and lower rates of labor participation among urban townships. The differences due to individual socioeconomic levels may be more obvious in less deprived areas. The study also suggests that enhancing industrialization in a rural area could lower alcohol-related mortality. Nonetheless, there are presumably both positive and negative effects associated with industrialization in public health terms. Putting aside the potential negative effects, industrialization may result in higher pay for local workers, in which case advocating for greater industrialization is actually about creating a better standard of living and providing job security rather than about industrialization per se. Thus, a policy aimed at enhancing opportunities for better paid employment should be recommended in these areas. As alcohol consumption in Taiwan continues to increase, policy makers should place greater emphasis on addressing the inequality of socioeconomic conditions among districts in order to diminish the impacts of such inequalities with regard to alcoholic diseases.

The present study also determined that the rate of residents married or living with family, the home ownership rate and the accessibility of health-care facilities in a community were not correlated with the alcohol-related mortality. Although household income was excluded in our analysis, past studies have revealed that neither mean income nor income inequality were related to alcohol-related mortality (Blomgren et al., 2004; Rosicova et al., 2011). A health survey for England showed that higher income populations consumed alcohol more frequently, and had a higher prevalence of binge drinking than people in lower income groups (Craig and Mindell, 2006). In the present study, the correlation coefficient for income and education was high ($r = 0.853$) and both VIFs were greater than eight. This suggests that the income variable was collinear with education. As education explained more of the variation in the model than income, household income has been excluded in our study. We hypothesize that the previous reported effect of income on mortality might instead be due to differing levels of education. Additionally, a study in Finland suggested that the higher alcohol-related mortality in more deprived groups may be due to higher incidences of alcohol-related morbidity rather than poorer survival (Makela et al., 2003). However, inequalities in access to health care are known to exist for many illnesses, with socioeconomically disadvantaged individuals receiving different interventions than more advantaged individuals (Erskine et al., 2010). An American study also observed that lower mortality may be due to factors other than alcohol consumption such as medical care and social integration (Rostron, 2012). Our finding in this regard is not consistent with the previous study, and it is suspected that this is because there are ever-present and inexpensive medical services available in Taiwan as a result of the National health insurance system. The possibility of access to medical treatment may be less different across townships in Taiwan than in the USA. This may attenuate the effect of health care on ARM as our study presented.

**Study strengths and limitations**

Autocorrelated residuals occur in many standard regression analyses where the dependent variable is itself autocorrelated. It should be mentioned that autocorrelation may be problematic because it violates the assumption of independence of errors held in classical linear regression models, and, in doing so, the estimates for the model’s parameters are biased. Nonetheless, only a limited number of studies exploring the relationships between alcohol-related mortality and socio-demography using techniques from spatial statistics have been published. The strengths of our study are the nationwide spatial analysis as well as the urban-rural stratified design. This study utilizes smaller spatial unit data from a large nationwide sample generated by linking administrative databases, which has various advantages for reviewing differences between areas within a country and for formulating area-tailored preventive policies (Rosicova et al., 2011).

Despite these strengths, there are also some limitations in the present study. First, other potentially relevant factors such as obesity levels and nutrition status were not included in our study. This could result in residual confounding by these variables in analyzing the relationships between socioeconomics and mortality. Moreover, the possibility that the associations seen at the area level are different than those which exist at the individual level cannot be ruled out (Connolly et al., 2011).

**CONCLUSION**

This study provides significant evidence that township-level relationships between alcohol-related mortality and socioeconomic variables exist in Taiwan. By using geographic districts complemented with the associated risk factors detected for them, public health policy makers could better prioritize the specific areas in which comprehensive interventions should be undertaken. That said, a fuller understanding of the mechanisms underlying the effects of area measures of socio-demographic structures on alcohol-related mortality is still needed.

**ACKNOWLEDGMENTS**

The authors thank Dr Tzai-Hung Wen for assistance with socioeconomic data collection and map generation.

**FUNDING**

This work was supported by grants from the National Science Council of Taiwan [grant number NSC 102-2410-H-130-054].

**CONFLICT OF INTEREST STATEMENT**

None declared.

**REFERENCES**


