Spatial patterns and covariates of heart disease death rates in Michigan, 1998-2004
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Citation

Abstract
Using the 1998 through 2004 data from the Michigan Resident Death Files, this paper examined the changing spatial patterns of heart disease death across Michigan counties and assessed the association between heart disease deaths and selected socioeconomic risk factors among people aged 50 years and older.

Methods: Tertiles of low, medium, and high rates were derived for 3-year moving averages of heart disease death rates for the counties.

Results: Overall, the mortality rates declined over time. Areas of low mortality rates expanded over time while the number of counties with high rates decreased. The regression analyses showed that primary level of education or less, unemployment rate, median household income, poverty rate, and lack of health insurance were each significantly associated with heart disease mortality.

Conclusion: The difference in the spatial pattern of heart disease deaths across the counties suggests a significant difference in the distribution of the underlying factors in Michigan communities. While our results indicate that the socio-economic environment plays a significant role in heart disease mortality in the state, more researches are needed to investigate these factors at the individual level.

INTRODUCTION
Despite the steady decline in heart disease-related mortality in the United States since the 1960s (American Heart Association 1997, Pickle and Gillum 1999), Heart diseases remains the leading cause of death in Michigan (Michigan Department of Community Health [MDCH] 2006). The MDCH reports that in 2004 heart disease accounted for as much as 29.1% of all deaths in the state, followed by cancer (23.1%). While heart disease accounts for the largest proportion of deaths at the state level, little is known about the geographic component of the rate of this health outcome within the state. Local patterns of high or low heart disease mortality rates may be a telltale blush for the spatial distribution of underlying factors. For example, spatial autocorrelation analysis of vascular mortality variables and risk factors in Eurasia (Peter et al. 1996), which revealed a north-south trend for death from cardiovascular and ischemic heart diseases, showed the same pattern for diastolic and systolic blood pressure and body mass index. The study also showed local patches for total serum cholesterol. Residential type also has an impact on heart disease outcome, with significantly higher risk of coronary heart disease mortality, for instance, occurring in rural and remote populations compared to metropolitan communities (Taylor et al. 1999). A number of ecological level studies have shown that geographic variation in heart disease mortality is associated with the socio-economic environment (Killoran et al. 1990, Bryce et al. 1994, McLoone and Boddy 1994, Djietror 2003).

The ultimate goal of this study is to examine the changing spatial patterns of heart disease death across Michigan counties and assess the association between the heart disease deaths and selected socioeconomic risk factors among people aged 50 years and older. Findings from this study will not only assist in identifying local populations at particular risk for heart diseases, but also inform population-based heart disease prevention interventions in the state.

METHODS
Study area: Michigan, which is part of the Midwest region of the United States, extends north-south approximately from Latitude 42°N to 48°N and east-west approximately from Longitude 84°W to 90°W. The state is divided into 83 counties. These are grouped into 6 sub-regions based on the Michigan Diabetes Outreach Network (MDON) operational
regions, namely Upper Peninsula (UP), Northern Michigan, East-Central Michigan, West & Central Michigan, Southern Michigan, and Southeast Michigan (Figure 1). The last five regions are collectively referred to as the Lower Peninsula (LP). The above grouping of Michigan counties is adopted for this study on the basis of the fact that diabetes is a major risk factor for cardiovascular outcomes (Gensini et al. 1998; Henry 1998; Laasko 1998; Cheang 2006; Petri et al. 2006); and regional differences in the realization of MDON’s mission – the prevention, detection and management of diabetes – are expected to influence the spatial pattern of heart disease outcome rates across the counties.

Data: The data on socio-economic variables came from the 1990 and 2000 censuses, which are freely accessible by the public at the U.S. Census Bureau’s website. Seven independent variables were selected based on a conceptual model for the investigation of underlying causes of geographic variation in cardiovascular disease outcomes (Djietror 2003), and on the heart disease risk factor literature. The following selected variables were used in this study: educational attainment (Shestov et al. 1993; Elliott and Dean 1998), income inequality (Kawachi et al. 1997), unemployment (Mattisson et al. 1990; Brener 1997; Elliott and Dean 1998), housing tenure (Tunstall-Pedoe et al. 1995; Sundquist and Johansson 1997; Nilsson et al. 1998), income (Lemstra et al. 2006; Winkleby et al. 2007), poverty rate (Pearson 2003), and per cent of a county’s population without health insurance (McWilliams et al. 2004; James et al. 2007).

Data from the Michigan Resident Death Files were used for this study. They are freely accessible by the public at the Michigan Department of Community Health (MDCH) website. Heart disease death rates were used as our outcome variable. Three-year moving averages of heart disease mortality rates for Michigan counties were extracted from this data set for the periods 1998-2000, 1999-2001, 2000-2002, 2001-2003, and 2002-2004. The death rates are per 100,000 and are computed by the direct method, using the age distribution of the total population of the United States for the year 2000 as the standard population (MDCH 2006). Although the manner in which underlying cause of death is coded and classified was revised in 1999, the high comparability (0.99) between classification schemes for this particular cause of death means that the change is not expected to have a significant impact on the comparisons of mortality statistics over time (MDCH 2006).

While the file on socio-demographic characteristics and that on heart disease death rates were collected and maintained by different institutions, they were compiled for the same population at the same spatial resolution – Michigan counties, which are the units of analysis in this study.

STATISTICAL ANALYSES:

The county level outcome data are categorized into tertiles of low, medium, and high rates of heart disease mortality, and analyzed for two cohorts: age 50-74 and age greater than or equal to 75 years. Among the 50-74 years cohort the categorized rates were: 100.7 – 311.1667 (low); 311.1668 – 377.1667 (medium); and 377.1668 – 650.9 (high). For the latter cohort the low, medium, and high rates are 925.9 – 2668.5320; 2668.5321 – 3029.3128; and 3029.3129 – 4535.4 respectively. Choropleth maps were prepared to show the spatial distribution of these categories across the counties in the six sub regions for each age group.
population groups were regressed on each of the seven independent variables with the view to assessing the degree of their association. In order to study changes in the strength of this association over time, the bivariate regression models were estimated for the initial (1998-2000), middle (2000-2002), and ending (2002-2004) three-year moving average periods. Due to a high degree of collinearity among the independent variables, the derivation of any useful multiple regression models was precluded.

RESULTS

ALL AGES COMBINED

Figure 2 shows the spatial pattern of low heart disease deaths by county for the entire Michigan population during the first and last three-year moving average periods. At the beginning, the counties with low rates were located mainly in the West-Central and Northern Regions of the LP. There was an isolated occurrence of low death rate in the UP (Keweenaw County). By 2002-2004, 9 counties in more or less the eastern half of the peninsula experienced a reduction in heart disease death rates. In the LP the number of low death rate counties increased phenomenally (more than four-fold) from 11 in 1998-2000 to 46 in 2002-2004. The expansion in the areas characterized by low death rates occurred mainly in Northern, West-Central, and Southern Regions. It is noteworthy that all the counties in the LP that had low death rates at the beginning of the study period held ground till the end of the period.

The spatial pattern of high heart disease death rates is depicted in Figure 3. During the study period there was substantial shrinkage in the areas that experienced high death rates. In 1998-2000, 44 Michigan counties had high heart disease death rates. This number decreased by 75% by the last three-year moving average period. The high rates persisted in the more or less extreme west of the UP and in the East-Central Region of the LP.

Most of the counties with medium death rates (22 out of 27) experienced a decline in heart disease deaths, and joined the low-rate category in by the of the study period. Only one county (Hillsdale) from the medium rate group at the beginning of the period had high heart disease death rate by 2002-2004.

Table 1 shows the bivariate regression results for all ages combined during the study period. The analysis revealed that educational attainment, unemployment rate, median household income, living in poverty, and no health insurance are independently associated with heart disease deaths in the State.

**Table 1: Bivariate regression results for all ages combined**

![Table 1](image)

**Figure 4**

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**Figure 3**

![Figure 3](image)

**Figure 3: Counties with high heart disease mortality rate in Michigan. Comparing three-year moving averages for 1998-2000 and 2002-2004. (All ages combined)**

**POPULATION AGED 50-74 YEARS**

During the study period there was more than a five-fold increase in the number of Michigan counties (9 to 48) with low rates of heart disease mortality for the population aged 50-74 years. During the 1998-2000 period, no county in the UP had low heart disease mortality rate (Figure 4). By 2002-2004, however, the mortality rates improved in six of the UP counties, namely Baraga, Alger, Delta, Menominee, Mackinac, and Chippewa. This development and spatial expansion of the areas with low heart disease mortality rates in the UP seems to have been concentrated in the central and eastern part of the peninsula between 1998 and 2004.
In the LP there were three core areas where low heart disease mortality rates persisted during the period studied. In 1998-2000 these core low-rate areas were located in Leelanau, Grand Traverse, Missaukee, and Ostego in the Northern region; Ottawa County in the West-central region; and Clinton, Washtenau, Livingston, and Oakland in the Southeast. They expanded spatially over time thanks to improvements in the mortality experience of a large number of neighboring counties, particularly in the Southeastern, East-central, West-central regions, and in the western part of the Northern region.

The data show that of the 22 counties with medium heart disease death rates for this cohort at the beginning of the period, 18 made the low-rate list by the end of the period. Only one county from the group in question made the high-rate list.

The areas characterized by high mortality rate, on the other hand, diminished over time. During 1998-2000 all but two of the counties (Keweenaw and Delta) in the UP had high heart disease mortality rates for the population aged 50-74 years (Figure 5). By 2002-2004, however, only three counties – Keweenaw, Ontonagon, and Iron (all in approximately the western third of the UP) – had high rates of heart disease mortality. As many as 39 counties had high mortality rates across the five sub-regions of the LP at the beginning of the study period. This number dwindled to 8 counties in three sub-regions by 2002-2004. High mortality rates persisted throughout the study period for this segment of the adult population in Ontonagon in the UP and Roscommon, Iosco, Lake, Clare, Genesee, and Wayne in the LP.

The regression analyses show that for the population aged 50-7 years, poverty rate has the strongest independent association with the outcome variable throughout the study period (Table 2). Educational attainment, median household income, and lack of health insurance are also significant covariates. Unemployment rate and income inequality exhibit the weakest associations with heart disease mortality rates for this cohort during the study period.

**POPULATION AGED GREATER THAN OR EQUAL TO 75 YEARS**

Between 1998-2000 and 2002-2004 the number of counties with low heart disease mortality rate for this cohort increased almost four times (from 13 to 51). At the end of the period these low-rate counties were concentrated in the central and eastern part of the UP, and mainly in the Northern, West-central, and Southern regions of the LP. The spatial dynamics of the pattern of low heart disease mortality rate among the population aged greater than or equal to 75 years is worth noting. At the beginning of the period there were three isolated occurrences of low rate in Keweenaw, Gogebic and Schoolcraft in the UP (Figure 6). While the occurrence of low rate in Gogebic disappeared by 1999-2001, it persisted in Keweenaw and Schoolcraft counties through 2002-2004 – expanding eastward and westward over time from Schoolcraft. In the LP low rates were persistent in Charlevoix, Otsego, and Missaukee (Northern region), and Allegan (West-central region); and nearly so in Leelanau, Lake, Newaygo, Kent, Ottawa, and Washtenaw. The latter counties made the low-rate list in 1999-2001 and maintained this rate for the rest of the period studied. Overall, the spatial expansion in the areas characterized by low heart disease mortality rate for this segment of the population in the LP was oriented northeast-southwest across the northern half, and east-west across the southern half, of the LP (Figure 6).
The number of counties with medium rate of heart disease mortality for the population aged greater than or equal to 75 years fluctuated between 1998-2000 and 2002-2004. Overall, however, it declined by about 35%. Of the 32 counties with initial medium mortality rates in 1999-2001, 24 made the low-rate list by the end of the period. Similar to the case for the population aged 50-74 years, only one county made it into the high-rate category. The spatial distribution of medium rates of heart disease mortality among this cohort was somewhat random during the study period.

In Michigan as a whole, the number of counties with high heart disease mortality rates in the population aged greater than or equal to 75 years decreased considerably (from 38 to 12) between 1998-2000 and 2002-2004. High rates characterized ten counties in the UP at the beginning of the study period (Figure 7). By 2002-2004 only four of these counties – Gogebic, Ontonagon, Baraga, and Marquette – had high mortality rates. In the LP the number of high-rate counties for this segment of the population decreased from 28 in 1998-2000 to 8 counties concentrated in the eastern half of the LP in 2002-2004. High heart disease mortality rates for this cohort persisted throughout the study period in three counties (Ogemaw, Bay, Gratiot, Lapeer, St. Clair, and Wayne) in the LP.

The regression analyses showed that only one bivariate model was significant for this age cohort: educational attainment was associated with heart disease mortality in the 2000-2002 moving average period (R² = .055; p=.033).

**DISCUSSION**

This exploratory county-level study reveals systematic spatial patterning of heart disease mortality in Michigan. Overall, the rate of heart disease mortality declined during the six-year period. The areas which experienced low heart disease mortality rate among Michigan’s adult population expanded between 1998 and 2004. On the other hand, there was considerable decrease in the number of counties characterized by high rate of heart disease deaths. For all the cohorts studied the death rates of “medium-rate” counties gravitated toward the low-rate category during the study period. This highlights the spatial dynamism in the declining rates of heart disease mortality across Michigan counties over time.

The declining rate in the state is consistent with the falling rates of cardiovascular mortality in the United States in recent times (Pickel and Gillum, 1999; McCarron et al. 2006; Ezzati et al. 2008). This study shows, however, that the decline has not occurred uniformly across the counties in Michigan. Overall, the southwestern part of the state (i.e., the West-central and Southern regions) experienced more decline compared to counties in the Upper Peninsula and the eastern half of the Lower Peninsula. At a more localized level, the eastern half of the Upper Peninsula experienced...
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greater diminution of the area characterized by high mortality rates for both cohorts (to the extent of total disappearance [Figures 5 and 7] by the end of the period studied) than the western half of that region. In the Lower Peninsula, high mortality rates persisted mainly in the Northern, East-central, and Southeast regions (Figures 5 and 7). The geographic locations where high mortality rates occurred also shifted during the period.

There are few counties in the state where the heart disease mortality rate seems to have stabilized either at a high or low level. Throughout the period low mortality rates persisted in Grand Traverse, Missaukee, and Otsego for both cohorts (Figures 4 and 5). Conversely, the mortality rate in Wayne and Ontonagon remained high throughout the period regardless of age (Figures 5 and 7).

These spatial patterns provide bases for hypotheses about regional differentiation of the underlying factors. For instance, the increase in the number of counties with low heart disease mortality rates, along with the persistence of high rates in some counties throughout the period studied, suggest that the factors driving the declining rates are not impacting Michigan communities equally. Also, as cardiovascular and pulmonary mortality rates vary among regions and places of varying levels of urbanization (Gillum 1994; Barnes et al 1996), an exploration of reported risk factors by level of urbanization may enhance an understanding of the spatial patterns revealed in this study.

This study corroborates the findings of previous studies showing significant spatial variability in the rates of decline in cardiovascular disease mortality (Sempos et al 1988; Wing et al 1990; Wing et al 1992). The shrinkage of areas with high mortality rates, along with the increasing number of counties characterized by low rates, flags spatial shifts in the burden of heart disease mortality, as well as morbidity, and the associated risk factors in Michigan. These spatial patterns may inform the development and targeting of heart health programs, including the evaluation of program activities.

The regression analyses revealed that no multiple regression models are significant due to the co-linearity of the independent variables explored. The bivariate regression results suggest, nevertheless, that there are a variety of fronts from which the heart disease mortality burden in the state might be tackled. With the exception of educational attainment (high school or higher education), the selected risk factors show no association with the mortality outcome for persons aged 75 years and over. This finding is significant because it indicates that a different set of underlying factors drive heart disease mortality experience for this age group. Furthermore, it suggests that from population health and demographic standpoints, the tailoring of heart disease risk reduction interventions in Michigan need to be age-specific. Finally, this study highlights the need for detailed research to identify what factors account for the spatial variations in heart disease mortality among the elderly in the State.

This study has some limitations. The aggregated data posted at the various websites did not allow us to provide the basic description of the subjects studied; nor did it allow us to categorize the age differently. We compared people aged 50-74 years to those 75 and older. Comparing people 50-6-, 61-70 and 71+ would have been more informative.

References
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