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Childhood drowning in Georgia: A geographic information system analysis

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A B S T R A C T

Drowning is one of the major causes of childhood mortality from unintentional injury in the United States. This study aims to delineate the drowning hot spots by aquatic environment and to examine the socioeconomic characteristics of neighborhoods with high densities. Drowning death records (2002–2008) among children aged 0–17 were obtained from the Office of the Child Advocate in Georgia. Drowning victims are initially analyzed by race, gender, age, aquatic environment, use of a personal floatation device, and the security of a pool. Using kernel density estimation and LISA statistics, this paper delineates drowning clusters by density and rate respectively. High-density neighborhoods are then investigated using a variety of socioeconomic factors by multiple-comparison test, Ordinary Least Squares (OLS) regression, and Geographically Weighted Regression (GWR). The result shows that the majority of victims were white, male, and children aged 0–4. Private swimming pools and open water were two leading drowning places. Blacks were more likely to drown in public swimming pools and in children aged 5–14 than white counterparts. Private swimming pools and children aged 0–4 have seen more white victims than blacks. Substantial spatial variation in drowning density and rate is present in Georgia. High-density drowning neighborhoods had a significantly lower rank of median income ($p < 0.01$) and lower rank of educational attainment in their counties than the low-density group. The GWR results suggest such associations vary in space. This study highlights the role of different socioeconomic factors in the interconnections of drowning risk factors. Findings suggest that health policies and prevention campaigns may be customized based on specific aquatic types and risk factors in different local communities.

Introduction

Drowning is a major cause of childhood mortality from unintentional injury in the United States (Cohen, Matter, Sinclair, Smith, & Xiang, 2008; Weiss et al., 2010). According to the Centers for Disease Control and Prevention (CDC) (2011), approximately one thousand children die from drowning annually in the US. Although it is relatively rare, drowning is the second leading cause of unintentional injury-related death among children 1–14 years of age (CDC, 2011). Despite that near-drowning events are nonfatal, they may cause brain damage and often require intensive medical treatment for the submersion injuries; some of the victims suffer from significant neurologic impairment and require long-term continuous care (CDC, 2011; Lee & Thompson, 2007; Weiss et al., 2010). Fatal drownings and near-drownings not only place emotional stress on the victims' families, but also are accompanied with substantial economic costs to the society: a lifetime cost of $384 million (Wintemute, 1990) and a hospitalization cost of $10 million per year (Cohen et al., 2008).

Previous studies have identified a number of risk factors for childhood drowning. Most studies found that risks are higher for males than for females and for children 1–4 years of age than for other ages (CDC, 2011; Lee, Mao, & Thompson, 2006; Weiss et al., 2010). The findings of differences in race and socioeconomic status for drowning risks, however, are mixed. Some studies found black youth, except preschoolers, have a higher drowning risk than white and Hispanic youth (Saluja et al., 2006; Warneke & Cooper, 1994; Weiss et al., 2010). One study (Brenner, Trumble, Smith,

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Kessler, & Overpeck, 2001), however, reported that the majority of victims were white. Furthermore, some researchers revealed that swimming pool drownings may increase with socioeconomic status because of elevated exposure to residential pools (Morgenstern, Bingham, & Reza, 2000; Weiss et al., 2010). But others (Hastings, Zahran, & Cable, 2006; Logan, Branche, Sacks, Ryan, & Peddicord, 1998; Saluja et al., 2006) argued that children in low-income families may have fewer opportunities to take swimming lessons and are more exposed to unfenced residential pools than their high-income counterparts. Another study (Saluja et al., 2006) reported that drownings for black children often occurred in public pools; on the contrary, white children were more likely to drown in residential pools. These mixed findings may partially result from the various aquatic environments involved with drownings (Brenner et al., 2001; Bull et al., 2003).

Although the types of aquatic environments in drownings are well known, few studies have been done to investigate drownings using Geographic Information Systems (GIS). GIS techniques, such as kernel density estimation and cluster detection, have been used for injury prevention (Anderson, 2009; Dai, Taquechel, Steward, & Strasser, 2010; Nagata et al., 2011). Geographic patterns revealed by GIS may be useful for injury prevention and preventive education. Drownings may occur in open water (e.g., lakes, ponds, creeks, and streams), bathtubs, buckets, swimming pools (private and public), wading pools, and other open standing water (Hastings et al., 2006; Quan, Pilkey, Gomez, & Bennett, 2011; Saluja et al., 2006; Weiss et al., 2010). Interventions to prevent drownings may be developed based on these aquatic circumstances (Brenner et al., 2009; Quan & Cummings, 2003). Programs in neighborhoods with frequent pool drownings, for instance, may enforce the installation of 4-side fences with self-closing/locking gates to secure the pools (Saluja et al., 2006; Stevenson, Rimajova, Edgecombe, & Vickery, 2003). Neighborhoods near natural bodies of water with frequent open-water drownings from recreational activities, on the contrary, may pay more attention to the use of personal floatation devices while boating or fishing (Weiss et al., 2010). A major challenge of improving the effectiveness of drowning interventions is to identify the specific drowning locations as they are often missing in reports. To develop effective prevention programs, it is thus very critical to identify the hot spots in neighborhoods experiencing frequent drownings and to understand their characteristics. If neighborhoods with frequent drowning victims based on different aquatic circumstances (pool, open water, etc.) could be identified, public health professionals could direct targeted interventions to these neighborhoods.

Inspired by the mixed findings in race and socioeconomic status as well as the challenge of implementing prevention programs, this study aims to (1) evaluate the demographic and locational characteristics of childhood drownings, (2) assess the spatial clustering of drownings and identifying the hot spots based on the aquatic environments of drownings; and (3) explore the physical and socioeconomic characteristics of neighborhoods with high drowning densities. The contribution of this research is twofold. First, it helps to understand the racial and socioeconomic disparities in drowning deaths in order to support the development of intervention programs accordingly. Second, neighborhoods where drowning victims are clustered may be targeted with focused intervention programs.

Study area and data

The study area is the State of Georgia in the southeastern United States. The choice of this study area is appropriate as Georgia has its crude rates of childhood drowning consistently outnumbering the national rates from 2000 to 2007 (CDC, 2011). The average 8-year crude rate in Georgia (1.79 per 100,000 children) ranked 12th among the 50 States and exceeded the average rate in the US (1.41 per 100,000 children) (CDC, 2011).

The Office of the Child Advocate in Georgia (OCA) provided child drowning death data ($n = 276$) from 2002 to 2008 based on the Child Fatality Review (CFR) documents. The data was collected by the Georgia Child Fatality Investigation Program in OCA, which is a partnership between the Georgia Division of Family and Children Services, the Georgia Child Fatality Review Panel, and the Georgia Bureau of Investigation. All fatalities in Georgia involving children less than 18 years old were investigated and reported. Each report represents an individual drowning case, including the victim's age, sex, race, residential address, the date of the event, and the drowning place categorized into 6 groups (open water, bathtub, public pool, private pool, wading pool, and others). Each case was also investigated for the use of a personal floatation device and the security feature of a pool if a pool drowning was involved. Due to the retrospective de-identified data, this study obtained an expedited review approval from the institutional review board without requiring informed consent. In ArcGIS 10 developed by Environmental Systems Research Institute (ESRI; Redlands, California), each victim's residential address was geocoded to a point (in latitude and longitude). In total, 220 cases (80%) were successfully geocoded. The locations of the remaining cases ($n = 56$) could not be identified because either their addresses were missing or only Postal Box numbers were available.

Other data includes census data, open water coverage, and swimming pools. The 2005–2009 American Community Survey (ACS) 5-Year Estimates at census tract level from the US Census Bureau (Census Bureau, 2011) was used to estimate the socio-demographic characteristics of the population in each census tract and county, respectively. Compared to Census 2000 Summary File 3 and the 2006–2010 ACS 5-Year Estimates, the 2005–2009 ACS was chosen because it matches most closely the period of the drowning data. Stream data, obtained from Atlanta Regional Commission (www.atlantaregional.com), was used to calculate the percentage of open water in each census tract. Public and private swimming pools ($n = 264$) were acquired from Reference USA (http://www.referenceusa.com), a reliable database often used in research (e.g., Dai & Wang, 2011; Raja, Ma, & Yadav, 2008). The census tract boundaries and county boundaries were obtained from ESRI (www.esri.com/data/download).

Descriptive analysis of childhood drowning

The analysis begins with a descriptive analysis of the geocoded drowning cases ($n = 220$) by their demographic and locational characteristics. Victims' ages were grouped into three categories (0–4, 5–14, and 15–17) following the age grouping in CFR and the census statistics in ACS. The results (Table 1) show that the majority of the victims were white, male, and aged 0–4. A large portion of the drownings occurred in open water or pools (85.46%), of which open water and private swimming pools were the most common accounting for 75.91% of drowning incidents. Most victims in open water did not wear any personal floatation devices (92.27%). Secured pools accounted for 14% of the pool drowning victims compared with 24% in unsecured pools and 62% in pools missing description of security. Regarding the white-black disparity, blacks had a higher drowning rate in public swimming pools with a rate ratio of 3.41 and a 95% Confidence Interval (CI) from 1.06 to 12.72. In addition, the rate is higher in black children aged 5–14 (rate ratio = 1.52 with a 95% CI of 0.84, 2.73) than the white counterpart.

Spatial variation in childhood drowning

The spatial variation was initially investigated by mapping the raw drowning counts and the rates considering the child