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Association of water temperature and submersion duration and drowning outcome

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ABSTRACT

Aim: Evaluate the roles of water temperature and submersion duration in the outcome of drowning victims.
Methods: Subjects were those who drowned in open water (lakes, rivers, and ocean) in three counties in Washington State between 1975 and 1996. We performed a case control study to assess the association between age, reported submersion duration, and estimated water temperature and drowning outcomes. Cases were victims with good outcomes (survival with normal or mild/moderate neurologic sequelae). Controls were victims with bad outcomes (death or severe neurologic sequelae or persistent vegetative state). We used Poisson regression to estimate odds ratios (OR) and 95% confidence intervals (CI).
Results: Of the total 1094 open water drowning victims, most were male (85%),white (84%), and with a mean age of 27 years. Most drownings occurred in lakes (51%) and in cold (≥6–16 °C (44%)) or very cold waters (<6 °C (34%)). Most (78%) had bad outcomes (74% died; 4% survived with severe neurologic sequelae. Of those with good outcomes, 88.2% were submerged <6 min, 7.4% 6–10 min and 4.3% for 11–60 min. Victims with good outcomes were 61% (95% CI 0.23–0.65) less likely to be submerged for 6 to 10 min and 98% (95% CI 0.01–0.04) less likely to be submerged for 11 or more minutes. Water temperature was not associated with outcome.
Conclusions: A protective effect of cold water for drowning victims was not found; estimated submersion duration was the most powerful predictor of outcome. Recommendations for initiation of rescue and resuscitation efforts should be revised to reflect the very low likelihood of good outcome following submersion greater than 10 min.

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1. Introduction

Drowning injury is a hypoxic injury. Its outcome is determined by many factors involving the victim, the environment, and the incident[1]. Among the possible environmental factors associated with drowning, cold water has been considered an important determinant of outcome because of its potential to induce the diving reflex and hypothermia. Both these conditions may be protective by decreasing metabolic demand and thus, the deleterious effects of hypoxia in a drowning victim.

The potential protective effect of cold water drives rescue and resuscitation efforts and the risks taken for drowning victims despite long periods of submersion with anoxia. Recently, Tipton and Golden proposed a decision-making guide for the search, rescue and resuscitation of a drowning victim that was dictated first by water temperature and second by duration of the submersion[2]. They proposed that following drowning in waters warmer than 6 °C, survival is extremely unlikely if submersion is longer than 30 min while in waters colder than 6 °C, survival is extremely unlikely if submerged longer than 90 min. Their decision-making guide was based primarily on expert opinion and review of anecdotal reports and very small case series.

The role of water temperature has significant pragmatic and safety implications. Ongoing discussions in our region highlight the need to address the cost benefit of adding more dive rescue teams costing more than $250,000 each per year and the risks

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to rescuers of performing water rescue in our region's hazardous, opaque, cold waters. Because of the methodological limitations of Tipton's and other reports proposing a protective effect of cold water on drowning outcome, we sought to evaluate the association between exposure to cold (6 to 16 °C) and very cold water (<6 °C) and submersion duration when drowning with good versus bad outcomes. We evaluated these factors using a unique, large retrospective database of open water drownings.

2. Methods

We performed a case control study of unintentional drownings in the Western Washington database. The victim's final outcome was determined by condition at initial hospital discharge. Cases were defined as victims with a good outcome, defined as those who survived with no, mild, or moderate neurologic sequelae including ataxia or dysarthria. Controls were defined as victims with a bad outcome, defined as those who died or survived with a persistent vegetative state or severe neurologic sequelae including no self-help skills or spastic quadriplegia.

The drowning database contains 2628 victims with drowning leading to hospitalization and/or death in King, Pierce, and Snohomish counties, Washington State, between January 1, 1974 and June 30, 1996. These counties include the city of Seattle and had 2,559,136 residents in 1990[3]. Their western edge is temperate coast; their eastern edge is the crest of the Cascade Mountains whose snow cover and many glaciers feed multiple major rivers and their tributaries. Additionally, this region contains hundreds of lakes, whose glacial silt creates poor water clarity.

The definition of drowning for those who died was made by pathologists at the medical examiner's offices in each of the three counties. The diagnosis of drowning for those who lived was based on the discharge diagnosis of drowning (ICD9 diagnosis code 994.1) made by physicians in the emergency department or hospital.

Using a form containing 346 variables, data for this database was abstracted from the investigative and autopsy reports of the medical examiner's office in each county, hospital records of patients with drowning (*International Classification of Diseases, 9th revision, clinical modification* (ICD9-CM) code 994.113) in the discharge registries of all 26 acute care hospitals, and incident reports of victims with a mechanism of drowning in the four major emergency medical services agencies in the region. Case finding was supplemented by using the computerized files of Washington State death certificates for all study years, and computerized files of state civilian hospital discharges with the diagnosis of drowning (ICD9 code 994.1) from 1987 through 1996.

Our study was limited to only episodes involving victims who drowned in open water, defined as lakes, rivers, and ocean, because estimated temperatures were available for these settings. We excluded pond, bath tub, pool and other container-related drowning because water temperatures could not be estimated for these bodies of water and rescue in these settings does not pose the high risk to rescuers nor require significant utilization of resources.

Data collected included variables related to the victim: age, sex, race (white or nonwhite, history of seizures, toxicology screen results; the drowning event: water temperature and submersion duration; type of open water: lakes, rivers, and ocean; and rural or urban (as defined by the US Census map for the time period). We categorized age groups as less than 5 years, 5 to 14 years, and 15 years or greater to reflect child, youth and adult body sizes. We used these age groups as a proxy for body surface area, a known determinant of cooling rates and potentially protective for cold water. The victim's submersion duration was defined as the first time estimate recorded after the submersion event. For example, if EMS was involved, estimated submersion duration documented in EMS records was chosen over estimates recorded in the intensive care unit charts. Submersion duration was categorized as <6 min, 6 to 10 min, >10–60 min, and >60 min. However, because survival was so low in the latter two categories, we combined them for most analyses.

Water temperatures were measured at the site following some of the incidents. The majority of temperatures were obtained following consultation with the data analysts of each of the following agencies who provided data based on measured water temperatures at locations nearest the drowning site and within days to maximum of a month of the event: Water temperatures were missing if the drowning site location was unknown or if measurements were not taken by the agency involved within the year/month of the drowning. The agencies were: for Puget Sound and the Pacific Ocean, the Washington State Department of Ecology's Puget Sound Assessment and Monitoring Program and National Oceanic Atmospheric Administration's National Data Buoy Center; for rivers, Washington State Department of Ecology River and Stream Water Quality Monitoring program; for lakes, King County Department of Natural Resources and Parks' Lake Stewardship Program, King County Major Lakes Monitoring Program, Washington State Department of Ecology's Environmental Assessment Program, Pierce Stream Team, and Snohomish County Surface Water Management. We categorized water temperature as greater than 16 °C (warm), 6 to 16 °C (cold), and less than or equal to 6 °C (very cold).

2.1. Statistical analysis

Because data were missing for some variables, we imputed missing data using a system of multivariate imputation by chained equations, resulting in 50 imputed datasets[4,5]. Variables that successfully predicted injury outcomes in the non-missing data and variables that successfully predicted the likelihood of missingness were included in a multivariate model that over 10 iterations refined the prediction of missing data. The process was duplicated 20 times to produce 20 multiply imputed datasets. The results of these datasets allowed us to model both the point estimates and the variance, or accuracy, of our imputed data.

We compared victim and event characteristics among drowning victims with good and bad outcomes including characteristics that have been shown to be associated with outcomes[6–9]. Our primary goal was to evaluate the effects of submersion duration and water temperature on outcomes.

We performed multivariate analysis and, because the outcome was not rare, used Poisson regression to estimate relative risks (RR) and 95% confidence intervals (CI) directly. Applying Poisson regression to binary outcome data can overestimate the standard error of the relative risks; however, this is overcome by using robust standard errors[10,11]. Our model was adjusted for age *a priori*. We assessed for potential confounding by sex, race, history of seizures, and toxicology screen results, and found no confounding. We used Stata Statistical Software (Stata/SE version 11.1, StataCorp. 2009.) for all analyses.

3. Results

A total of 1377 victims who drowned in open water in Western Washington was identified in the database, 1094 of whom suffered unintentional submersions. Most victims were white (84%), male (85%), and with a mean age of 27 years. Most drownings occurred in lakes (51%), followed by rivers (26%) and ocean (23%), and primarily occurred in rural regions (65%). Boats were involved in 25% of drownings. Most drownings occurred in cold (44%) or very cold waters (34%). Most submersion durations were greater than 10 min

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