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Association of water temperature and submersion duration and drowning outcome

Linda Quan[a,b,*], Christopher D. Mack[a,c], Melissa A. Schiff[d,e]

[a] Department of Pediatrics, University of Washington School of Medicine, Seattle, WA, United States
[b] Department of Emergency Services, Seattle Children's Hospital, Seattle, WA, United States
[c] Group Health Research Institute, Seattle, WA, United States
[d] Department of Epidemiology, University of Washington, School of Public Health, Seattle, WA, United States
[e] Harborview Injury Prevention and Research Center, University of Washington, Seattle, WA, United States

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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.

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

* Corresponding author at: Seattle Children's Hospital, Emergency Services MB.7.520, 4800 Sand Point Way NE, Seattle, WA 98145, United States.
Fax: +1 206 729 3070.
E-mail address: linda.quan@seattlechildrens.org (L. Quan).

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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

Table 1
Victim and event characteristics of open water drowning victims by outcome, Western Washington State, 1974–1996.

	Good outcome (N = 276) (%)	Bad outcome (N = 818) (%)	Proportion missing in unimputed data
Victim characteristics			
Age (years)			0
0–4	31.6	6.2	
5–14	20.5	9.7	
15–24	14.9	31.4	
25–34	12.6	23.5	
35–64	19.3	23.2	
65+	1.1	6.0	
Male sex	75.1	88.7	0
Race			
White	85.8	82.9	3.2
Non-white	14.2	17.1	
History of seizures	4.0	4.0	5.9
Suspected alcohol or illicit drug use	17.9	30.7	19.6
Event characteristics			
Type of body of water			0.0
Lake	61.2	47.5	
River	13.1	29.9	
Ocean	25.7	22.6	
Location			
Urban	44.6	32.1	4.8
Rural	55.4	67.9	
Water temperature (°C)			0
<6	31.9	34.9	
6–16	40.6	44.7	
17+	27.4	20.4	
Submersion duration (minutes)			45.2
<6	88.2	4.7	
6–10	7.4	5.0	
11–60	4.3	23.4	
>60	0.1	66.9	

Table 2
Multivariate predictors for good outcome in open water drowning victims.

Characteristics	Adjusted RR (95% CI)
Age (years)	
0–4	1.34 (1.01, 1.79)
5–14	1.33 (0.96, 1.85)
15+	1.0
Submersion duration (minutes)	
<6	1.0
6–10	0.39 (0.23, 0.65)
11+	0.02 (0.01, 0.04)
Water temperature (°C)	
<6	1.0
6–16	1.13 (0.84, 1.52)
17+	0.97 (0.71, 1.33)

(69%). Bystanders provided cardiopulmonary resuscitation (CPR) to approximately 29.9% of victims. EMS administered CPR to 23% of the victims.

Good outcomes occurred in 22%. Bad outcomes included the 74% of victims who died and the 4% who survived who had severe neurologic sequelae or persistent vegetative states. Compared to those with bad outcomes, victims with good outcomes were more likely to be younger (<15 years of age), female, have a submersion time less than 6 min in waters ≥16 °C. Among those with good outcomes, 88.2% were submerged <6 min, 7.5% for 6–10 min, 4.3% for 11–59 min, and <1% for greater than 60 min (Table 1). Half (50.2%) of those with good outcomes compared to 21.5% of those with bad outcomes received bystander CPR while 12.4% of those with good outcomes and 96.7% of those with bad outcomes received CPR by EMS.

In our multivariate model (Table 2), victims with good outcomes were 34% (95% CI 1.01–1.79) more likely to be 0 to 4 years of age. Compared to those with bad outcomes, victims with good outcomes were also 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. We found no association between good outcomes and water temperature in the study population.

4. Discussion

In this case control study using multivariate analysis of a large population-based data set, submersion duration and age were the factors associated with good outcome among drowning victims. We found no association between water temperature and outcome following drowning.

Our finding that submersion duration was the key predictor of outcome agrees with Suominen's studies that incorporated data on victim age, water temperature, and submersion duration using multivariate analysis[9,10]. All 38 victims with good outcomes were submerged <22 min. In another study of mostly open water drownings, no one of 250 with cardiac arrest survived when submerged >15 min in waters >15 °C[13]. Our findings support the statement by Tipton et al. that "if water temperature is warmer than 6 °C, survival/resuscitation is extremely unlikely if submerged longer than 30 min"[2]. Our data suggest that this statement is also true for water temperatures of 6 °C or below since no victims in our database had good outcomes if submerged more than 27 min in these water temperatures.

Our analyses suggest that Tipton's statement that "survival/resuscitation is extremely unlikely if submerged longer than 90 min in 6 °C or below waters" is overly permissive. Tipton's upper limit might be interpreted as supporting the prevalent belief that drowning victims have a "golden hour" in which all efforts should be made to rescue and resuscitate, requiring enormous resources and putting rescuers' lives and safety at risk. Importantly, this study demonstrates the likelihood of good outcome follows a rapidly declining trajectory in minutes after submersion, rather than a simple cutoff at 60 or 90 min.

Importantly, reported submersion durations usually represent the absolute minimum time period of anoxia the patient

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experienced, an estimate the bystander provides, "he's been under *x* minutes". However, the total duration of victim anoxia includes the time interval between the time of recognition of drowning or submersion to initiation of CPR. This time interval includes several time consuming components unique to drowning events. It includes the time to (a) make a call (including finding one's cell phone or the beach's phone), (b) describe the situation to dispatch (multiple telephone transfers within the EMS phone triage system, providing dispatcher the history, patient identification and location), (c) retrieve the victim from the water (including walking or diving into the water, locating the victim, and getting him to shore or boat), and (d) initiate CPR. Accurate time data for these time intervals are only described when EMS is involved wherein common measures include time of call, time of arrival at the scene, and time to EMS-provided CPR. In 250 drowning cardiac arrest emergency calls in Sweden, the time interval from cardiac arrest to call was 4 min, interval to ambulance arrival was 11 min, representing an average total delay of 15 min, range 8–23 min. In addition, getting the victim out of the water onto land or boat where CPR can be started requires time and significant effort. In drowning rescue simulations at a beach with surf lifeguards, time interval to start of ventilations in the water was 155 s and to the start of CPR, 258 s[14]. Thus, submersion duration is only a portion of the total duration of anoxia for most drowning victims.

Our study found no effect of water temperature on outcomes, although cold water submersion is hypothesized to produce protective hypothermia and the dive reflex. Physiologic studies show that the dive reflex occurs but is very transient, and is rapidly superseded by marked atopic tachycardias and hypertension[15,16]. Golden estimated that the development of central hypothermia in an adult requires immersion for 30 min in cold water[17]. By the time central hypothermia is achieved, 30 min of submersion would result in irreversible anoxic organ damage. Most clinical studies demonstrate the failure of hypothermia to protect; hypothermia in a drowning victim on arrival to the emergency department has been repeatedly shown to be associated with a bad outcome and predicted bad outcome even in those treated aggressively with extracorporeal membrane oxygenation[18–23].

The protective role of water temperature has not stood the test of rigorous clinical studies. Reviewing anecdotal reports of drowning survivors, Orlowski concluded that cold water was protective only if the water was <5 °C[24]. In a non-metanalysis review of assorted cases, Tipton reported that most survivors of submersions >5 min had drowned in waters <7 °C. In a stronger study design in 250 drowning victims, outcomes were not better among those drowning in <6 °C or <15 °C waters[12]. Using a robust study design, this and Suominen's multivariate regression studies showed no association between cold water and outcome[8]. Importantly, our study involved an inclusive database of drownings while others have reported on only segments of the drowning population, such as children, those who were hospitalized, those who received prehospital care, or coroner's cases.

The small effect of young age, <5 years, in predicting a good outcome in our analysis has not been found in other studies that have adjusted for confounding factors[8,9,18,20]. It is possible that the effect of young age is so small as to be only demonstrable in a large dataset such as this one as suggested by the lower limit confidence interval.

Our study had several limitations primarily related to retrospective data collection.

We believe that case ascertainment of drownings resulting in hospital admission was very high because we searched individual hospitals' registries for admissions for drowning as well as the state's computerized database of all hospital admissions. Similarly, case ascertainment of drowning fatalities was high because we searched the three counties' medical examiners' registries as well as the state's computerized death certificate files. The possibility of misclassification of drowning among these cases seems small since all received medical evaluation. In some cases, drowning may have been the secondary cause of death or injury.

Water temperatures were rarely collected at the time of the incident; therefore, most were estimated based on extensive existing regional water monitoring systems. However, it is unlikely that estimates were biased toward over or under estimation. Water temperatures in almost all rivers and lakes in this region of Washington State remain cold from mid-September to mid-June or July. Missing data was greatest for estimated submersion duration; we addressed this limitation with multiple imputation. This has been shown to produce superior estimates to a complete-case analysis[25].

Our study used data from 1975 to 1996. However, we believe the conclusions are generalizable to 2013. Despite anecdotal reports of good outcomes following therapeutic hypothermia and extracorporeal resuscitation, a 2012 evidence-based consensus was that current treatment of drowning injury was nonspecific, involving restoration and maintenance of normal physiology[26]. Of note, during our study period until the mid 1990s, therapeutic hypothermia was the national standard of care for children hospitalized after a significant drowning event. Therapeutic hypothermia ceased because various centers showed no improvement in outcome[27]. Also, an evaluation using this drowning database showed hospital care did not change in outcome over time[28]. Moreover, long term survival rates of pediatric patients who survived out of hospital cardiac arrest between 1985 and 2009 did not change over time[29,30]. We await higher levels of evidence, randomized controlled studies, to define the impact of present and proposed post resuscitation care on outcome.

5. Conclusion

In this large case control study of open water drownings, evidence for a protective effect of cold or very cold water for drowning victims was not found; instead, the estimated submersion duration was the most powerful predictor of outcome. Recommendations for initiation and duration of rescue and resuscitation efforts should be revised to reflect the very low likelihood of good outcome following submersion greater than 10 min. Further studies should evaluate the patient's total duration of anoxia, time from submersion to initiation of CPR since both primary and secondary anoxia contribute to the drowning victim's outcome.

Conflict of interest statement

None of the authors have anything to disclose.

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