

11-1-2008

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Recommended Citation

Avramidis, Stathis and Butterly, Ronald (2008) "Drowning Survival in Icy Water: A Review," *International Journal of Aquatic Research and Education*: Vol. 2: No. 4, Article 8.

DOI: <https://doi.org/10.25035/ijare.02.04.08>

Available at: <https://scholarworks.bgsu.edu/ijare/vol2/iss4/8>

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Drowning Survival in Icy Water: A Review

Stathis Avramidis and Ronald Butterly

We conducted an extensive literature review using the search terms of “drowning” and “hypothermia” to discover the major factors related to differences in survival rate especially associated with hypothermic effects. Studies indicated that some differences in drowning survival could be identified associated with age, sex, length of submersion, reduced core body temperature, and quality of cardiopulmonary respiratory care. The variability of results associated with the large number of studies prevented us from making any recommendations about whether hypothermia can improve survival among either children or adults.

Drowning is the seventh leading cause of accidental death around the world with the rates for both sexes of adults between the ages of 15–29 years old being reported as 78,639. Among children even higher rates of drowning are reported with 115,922 drowning deaths in the age group of 0–4 years, ranking it the eleventh leading cause of death in that age group, and 113,614 drowning deaths in the age group of 5–14 years, which ranks it the third leading cause of death (Peden, McGee, & Krug, 2002).

Drowning deaths exhibit a seasonal pattern in most parts of the world (Becker & Weng, 1998). While drowning seems to be more prevalent in warmer climates year round, the drowning rates in temperate and colder climates are still significant especially during the warmer summer months (i.e., June, July, August in the Northern Hemisphere and December, January, February in the Southern Hemisphere; see Manolios & Mackie, 1988; Royal Society for the Prevention of Accidents, 2001). People also drown in cold water after engaging in aquatic and other outdoor activities during the colder months of the year. Whether there are any particular differences in drowning outcomes between adults and children who have been immersed in cold water is a question that we feel needs to be investigated. We attempt in this article to answer the question of whether hypothermia actually might be advantageous, particularly to children who are accidentally immersed.

The most serious consequences of an immersion accident are hypoxia and its effects on the cardiovascular system and the central nervous system. The mammalian diving reflex and hypothermia might offer some protection to the central nervous system despite prolonged hypoxia (Sarnaik & Vohra, 1986), probably explaining some of the incredible survival anecdotes surrounding survival of drowning incidents. The adult human brain at normal body temperatures normally

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suffers irreversible damage if subjected to acute and resultant hypoxia for longer than 10 minutes. Significant resistance of brain tissue to hypoxia occurs only after its temperature has fallen from 37 to 30° C or less (Gooden, 1992). As we will shown in the paragraph below, the time required for decreasing brain temperature varies, depending on the temperature of the water, the thickness of the insulating fat layers, and the activity level of the person (Nielsen, 1978).

Some researchers (Holmer & Bergh, 1974; Sloan & Keatinge, 1973) found that children and adults who swam in cold water (i.e., below 30° C) had a significant decrease in core temperature below 35° C. Although temperature regulation does exist in the newborn human infant, it is not fully developed and is not controlled to the same degree as it is in adults (Edholm, 1978). Thus newborn infants are particularly prone to suffer from hypothermia (Schulman et al., 1998). The bodies of young children have a much lower mass-to-surface ratio than adults and cool at rates much faster than do adults (Sloan & Keatinge, 1973). They also thermo-regulate much less efficiently than adults and as a result the very young child's brain cools faster than an adult's does (Mansell, Fellows, MacDonald, & Allison, 1990). Other studies of infants and of the elderly have shown that a low body weight was associated with a reduced ability to thermoregulate and an increased risk of suffering from hypothermia (Craig, 1983), possibly because of their relatively low percentage of body fat. Based on this evidence, it appears that many young children, especially those with low body fat are at risk to hypothermia. Finally, if close attention is paid to many young children during swimming experiences such as during swim lessons, many can be observed to be shivering (Xu, Tikuisis, & Giesbrecht, 1999). During training swims in water at 20 °C, Keatinge (1978) suggested that the youngest children cooled fastest, because the younger children also were generally the thinnest.

Some studies found that when children have been in drowning accidents, hypothermia has not appeared to provide any protective effect (Suominen, Korpela, Silfvast, & Olkkola, 1997; Van der Lely & Vreede, 1998). On the other hand, one major study of childhood immersions in icy water has shown that of all survivors, some 70% suffer no long lasting effects (Pearn, 1992). Hypothermia and a variety of other factors have been suggested as important in explaining potentially successful recoveries even after some period of submersion. There is a need to identify the role that hypothermia may play as a possible protective mechanism in cold water immersions, especially among young children. In fact, the reduced body mass and increased relative surface area in young children may suggest both a survival mechanism as well as a need for different postdrowning treatments between adults and children. The aim of this review article is to evaluate whether there is any evidence that children have a greater chance for survival than adults after a drowning incident in cold water.

Method

The terms "drowning" and "hypothermia" were used as key words in a literature search that the authors undertook to identify literature that considered these two factors' influence on the outcome of drowning and that perhaps could differentiate between the chances of survival between adults and children. The search used electronic databases typically available in academic libraries (e.g., Medline). We

discovered that many research articles indeed were available in the literature and we followed a selection process choosing to include articles based on the following two criteria: first, articles referring to epidemiologic characteristics (e.g., age, gender, area of residence, time of occurrence) and second, articles referring to drowning and hypothermia in children and adults.

Following the initial broad literature search, we selected four variables (i.e., age, sex, duration of submersion, and resuscitation efforts) to examine to facilitate our critical review and arrive at more accurate conclusions about what the literature has to say about differences between the targeted groups of adults and children when it comes to surviving drowning incidents.

In terms of providing a common set of understandings for the present review, the first step was to define commonly used terminology. Drowning was defined as “the process of experiencing respiratory impairment from submersion/immersion in liquid. Drowning outcomes are classified as death, morbidity and no morbidity” (Dorp, Knape & Bierens, 2003, p. 6) and hypothermia is defined as “the reduction of the deep body (core) temperature to below 35° C” (Handley, 2006, p. 50).

Results

Age

Hypothermia associated with drowning in cold water, often accompanied by cardiac arrest, has a high rate of mortality, especially in adults (Waters, Belz, Lawse, & Ulstad, 1994). During the Second World War, many thousands of men and women died at sea when their ships sank. Analysis of survival times showed that survival was closely related to the sea water temperature in which the colder the water temperature, the shorter the survival time and the fewer the survivors (Edholm, 1978). On the other hand, we did find some limited case studies of adults who drowned in cold water and who occasionally survived (Huckabee, Craig, & Williams, 1996; Kumle, Doring, Mertes, & Posival, 1997; Nincevic & Mlinaric, 1995). Others attempted to identify the incidence, risk factors, and outcome predictors of 612 patients admitted to hospital because of accidental hypothermia. Among these subjects, one group of 185 patients (average age: 38.9 years) suffered hypothermia as a result of cold water immersion. The researchers concluded that old age was not an unfavorable prognostic factor for this group (Bierens et al., 1995).

In contrast, we discovered the literature presented a large number of reviews or case studies of young casualties who likewise drowned in cold water and survived (Antretter, Muller, Cottogni, & Dapunt, 1994; Biggart & Bohn, 1990; Fretschner, Kloss, Borowczak, & Berkel, 1993; Kemp & Sibert, 1991; Kyriacou, Arcinue, Peek, & Kraus, 1994). Several case studies confirmed that children under the age of 8 years with documented rectal temperature equal or less than 25° C after being immersed and without a pulse in a hypothermic environment subsequently had left the hospital without neurological consequences (Estebe et al., 1991; Fritz, Kasperczyk, & Galaske, 1988; Leitz, Tsilimingas, Guse, Meier, & Bachmann, 1989). Bierens, van der Velde, van Berkel, and van Zanten (1990) found that a young age actually seemed to be a good predictor for survival from drowning. This was supported by other studies that examined young subjects. For

example, one major study of survivors of childhood immersions found that 66% were completely normal, 30% suffered some selective deficits, and only 3% ended up living in a permanent vegetative state (Pearn, 1992). In another study that examined the cases of 330 children (age 14 years or less) involved in drowning incidents, 142 died before admission to hospital, and 188 children were admitted after nearly drowning (now called nonfatal drownings). The authors suggested that many surviving children can live normally after drowning (Kemp & Sibert, 1991). When hypothermia was involved in a drowning, it was found that children had an improved survival outcome (Antretter et al., 1994; Estebe et al., 1991; Krandick & Mantel, 1990; Leitz et al., 1989). In a few other studies the effect of rapid hypothermia caused by cold water immersion did not demonstrate an increased survival outcome by children in drowning incidents (Suominen et al., 1997; Veenhuizen et al., 1994). In those cases, some additional factor other than hypothermia explained their survival from drowning incidents (Gooden, 1992).

Sex

Differences in drowning rates do exist between the sexes. Specifically, males have a higher incidence of drowning across all age groups, as compared with females (Lindholm & Steensberg, 2000; Nieves, Buttacovoli, Fuller, Clarke, & Schimpf, 1996; Yamamoto, Yee, Mathews, & Wiebe, 1992). Interestingly, differences between the sexes also exist when comparing children in terms of hypothermia: Boys cool faster than girls. Sex does appear to interact with age but is not simply a result of the smaller body size of the youngest children. This may occur because on average, girls have greater subcutaneous fat than do boys at all ages. According to the same author (Keatinge, 1978), the youngest children begin to shiver seriously only when core body temperature falls below 35–36° C. Children, particularly small boys, are clearly very much at risk during any accident in water where they cannot leave the water as they cool down (Keatinge, 1978).

Duration of Submersion

One of the factors that has been found to affect the outcome of drowning is the length of submersion time (Elixson, 1991; Skarpnes, 1989). A study that examined the files of 83 submersion victims (males = 66, females = 17, average age = 31.4 ± 25.8 years) found that the prediction for survival is strongly related to submersion of less than 10 minutes when the body temperature is less than 35° C at admission. Nevertheless, the study concluded that no indicator at the rescue site and in the hospital was absolutely reliable for differentiating between a death or survival outcome (Bierens et al., 1990). Others found that submersion for over 5 minutes was prognostically unfavorable (Van der Lely & Vreede, 1998). Finally, another study evaluated the effect of submersion duration (submersion time ranges = 0.5–90 min, median time = 6.3 min) and water temperature (range = 0–37° C, median temperature = 16° C) on the outcomes of 48 nonfatal drowning by children (males = 37, females = 11, age range = 0.8–15 years, median = 3.7 years). The authors did not observe any potentially beneficial effect on the outcome of drowned children as a result of rapid hypothermia caused by submersion in cold water (Suominen et al., 1997).

Resuscitation

In Norway, the number of deaths per year from drowning is approximately 9 per 100,000 in the general population, most of them males between 25–40 years old of age who presumably were employed in water-related occupations such as fishing. Basic treatment was centered on effective cardio-pulmonary resuscitation (CPR; Vaagenes, 1993). Kyriacou et al. (1994) examined whether immediate resuscitation by rescuers or bystanders reduced the frequency of severe neurological damage or death in children after a documented submersion event. The authors found that children ($N = 66$, age range = 0–14 years) with a good outcome were more likely to have had immediate resuscitation than children with a poor outcome. A similar finding was supported by other studies that concluded that the single most important step in the treatment of submersion accident victims, especially children, is immediate and effective CPR on-site as well as in the emergency room (Kyriacou et al., 1994; Orłowski, 1987; Pruessner, Zenner, & Hansel, 1988; Robinson & Seward, 1987; Sarnaik & Vohra, 1986).

Discussion

Drowning is a leading cause of morbidity and mortality for both children and adults. According to some of the literature (Schulman et al., 1998; Sloan & Keatinge, 1973), children are more prone to experiencing hypothermia than every other age category among humans except perhaps the elderly, whose thermoregulatory mechanisms are extensively compromised (Craig, 1983). Ironically, this special vulnerability of a child to hypothermia who appears to be lifeless after a cold-water immersion, in fact, may produce a more favorable outcome in some cases (see Bierens et al., 1990; Pearn, 1992) although not in other cases (see Suominen, Korpela, Silfvast, & Olkkola, 1997; Veenhuizen et al., 1994). Early and rapid induction of deep hypothermia may have a protective effect on the brain. Favorable factors, most marked in early childhood, are both anatomic and physiologic (Estebe et al., 1991). The findings in both childhood and adulthood victims suggest that a young age may be a predictor of a positive survival outcome, at least in some cases. Obviously, because of the mixed findings, much more research is required for a clearer understanding of the relationship between hypothermia-related drowning casualties and age of the victim.

When the hypothermic effect of cold water is a good predictor of a successful outcome, then males, in contrast to females, have a greater possibility of survival after immersion in cold water, apparently due to suffering more rapid onset of hypothermia. This may be because girls have greater subcutaneous fat than boys do at all ages (Keatinge, 1978). Factors such as the length of submersion time, however, suggest much less positive outcomes. An approximate submersion time up to 5 minutes in icy water appears to allow survival by both children and adults (Bierens et al., 1990; Van der Lely & Vreede, 1998). A hypothermic state (i.e., core temperature less than 33°C) of submersion casualties may produce a slightly more favorable survival rate in both adults and children. The existing scientific evidence is somewhat suggestive, but certainly not conclusive that children may have a slightly greater rate of survival after a drowning incident in icy water than

adults have. There are other major factors (e.g., time of submersion, sex) that confound the results of the differences between children and adults.

Conclusion

From the results of our literature review conducted before composing this article, we conclude that the major conditions of a young age, male sex, submersion of less than 5 minutes, presence of hypothermia (below 33° core temperature), and immediate and high quality cardio-pulmonary resuscitative care tend to lead to increased survival after drowning in icy water. Because the literature contains such a mixed set of results, much additional review and research will be required related to these drowning factors to sort out clear results. We could not draw any generalizations at this time about whether to recommend changes in medical care applied for nonfatal drowning victims based on age or sex.

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