How much did cold shock and swimming failure contribute to drowning deaths in the fishing industry in British Columbia 1976–2002?

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Background
The Workers’ Compensation Board of British Columbia requested a retrospective analysis of all fishermen’s deaths from immersion in water in British Columbia.

Aims
To identify the underlying cause of drowning and make recommendations to improve safety in the fishing industry.

Method
Eighty-nine inshore and offshore fishing accidents were analysed. Where possible, deaths were classified into the four stages of cold-water immersion: cold shock, swimming failure, hypothermia and post-rescue collapse. Other factors that led up to the drowning were also identified.

Results
One hundred and thirty fishermen died from immersion between 1976 and 2002. One hundred and twenty-eight drownings were certified by the coroner as drowning or drowning/hypothermia and two were certified as cardiac event after immersion. The underlying causes of drownings were reclassified as: cold shock (5.4%), swimming failure (5.4%), hypothermia (5.4%), post-rescue collapse (0.8%), cardiac event (0.8%) and drowning/other (10%). In the remaining 72.2% of deaths, there was insufficient information to determine an underlying cause. All deaths occurred in water below 17.5°C but 95% were in water less than 15°C.

Conclusions
Immersion in water below 15°C is dangerous and this should be emphasized on marine survival courses. Accident investigators, coroners and pathologists need a common checklist to record vital data. A recommended format is included as Supplementary data available at Occupational Medicine Online. Fishermen should be educated about the dangers of sudden, unexpected immersion in cold water. Consideration should be given to making marine survival courses mandatory for fishermen.

Key words
Cold shock; cold-water immersion; drowning; fishing; swimming failure.

Introduction
In 1977, Schilling reported that the fatality rates for fishermen were twice that of coal miners and 20 times the rate of people in the manufacturing industries [1]. The International Labour Organization reconfirmed this in 1999. They estimated the worldwide fatality rate to be 80 per 100,000 workers, or approximately 24,000 deaths a year [2]. Fishing is a dangerous profession in British Columbia (BC) and has the highest fatality rate of any of the occupations supervised by the Workers’ Compensation Board (WCB). Regulations exist requiring the use of a lifejacket if the fisherman is exposed to the risk of drowning and requiring ship abandonment drills to be conducted at the beginning of each fishing season. However, there is no mandatory requirement to attend a marine survival course.

When the crew or a crewmember of a fishing vessel dies at sea, the most common cause written on the death certificate is ‘drowning’ or ‘presumed drowned’. However, writing this statement does not delve into the underlying cause of the drowning, making it difficult to revise regulations, design appropriate safety equipment and produce realistic training courses.

Molnar, in 1946 developed the first survival prediction curves in cold water [3]. He noted that the survival curve rose steadily for water temperatures above 60°F (15.5°C). In the same year, the Talbot Committee noted that during the Second World War, over 30,000 Royal Navy officers and men lost their lives due to drowning and that next to
drowning, cold from immersion and exposure was the most frequent cause of death [4]. In conjunction with this, McCance et al. recorded the loss of merchant sailors during the war [5]. The three causes of death were cold both before and after men reached the life raft, lack of fresh water and drinking seawater. In 1969, Keatinge produced the first textbook on Survival in Cold Water [6], and in 1976, Smith published a report titled ‘Survival at Sea’ [7]. At that time, it was generally accepted that hypothermia had led up to the principal cause of drowning.

In 1981, Golden and Hervey [8] reported on four stages in which death may occur during sudden, unexpected cold-water immersion. These were: stage 1, initial immersion, which kills within 2–3 min of immersion; stage 2, short-term immersion, which kills within 3–15 min of immersion; stage 3, long-term immersion, which kills after 30 min of immersion; and finally, stage 4, post-immersion, which kills during or shortly after rescue. In the survival textbooks and training courses, these stages have been called cold shock, swimming failure, hypothermia and post-rescue collapse.

University researchers of cold-water physiology had noted the four stages of immersion, but having accepted hypothermia as the principal cause of drowning, concentrated their efforts on taking action to prevent it. They considered the first two stages as an academic finding that occurred in the laboratory. Furthermore, the dangers of being immersed in water below 15°C had not been fully realized in the fishing industry. The Code of Safety for Fishermen and Fishing Vessels issued in 1975 by the International Maritime Organization [9] only made reference to hypothermia and no reference to cold shock, swimming failure, hypothermia and post-rescue collapse.

In view of the continuing loss of life in the BC fishing industry, the WCB of BC requested a retrospective analysis of all drownings reported to the Board between 1976 and 2002. The objectives were to identify the underlying causes of the drowning and recommend preventive measures.

Methods

Eighty-nine inshore and offshore fishing immersion accidents reported to the WCB of BC between 1976 and 1992 were reviewed. General data, such as size of vessel, water conditions, swimming ability, safety equipment worn, etc. were analysed. If water temperatures were not recorded, temperatures were calculated from the Fisheries and Oceans Canada sea-surface temperature database, or estimated. More specifically, where deaths were certified as ‘drowning’, they were recategorized (where possible) to identify the underlying cause as one of the four stages described by Golden and Hervey, these being cold shock, swimming failure, hypothermia and post-rescue collapse [8].

Criteria for making the diagnosis of death from drowning/cold shock were:
- Witnessed water entry
- Witnessed struggle before giving up and drowning
- Apparent death occurring within a very short period of time of immersion (approximately 5 min).

Criteria for making the diagnosis of death from drowning/swimming failure were:
- Witnessed water entry
- Witnessed swimming with increasing difficulty to stay afloat, increasing reduction in freeboard and ultimate disappearance in the water less than 30 min after water entry.

Criteria for making the diagnosis of death from drowning/hypothermia:
- A body-core temperature of 25.0°C or below after rescue
- A report of being alive in the water for over 30 min before being rescued
- Death from drowning due to hypothermia-induced unconsciousness, occurring at a body core temperature of 30–33°C
- Death from drowning with a reported body core temperature of or below 35°C.

Criteria for making the diagnosis of death from post-rescue collapse were:
- The victim was alive and coherent when in the water.
- The victims may have helped in their own rescue.
- On the point of, or shortly after rescue, the victim collapsed and died.
- There were no other apparent contributing medical causes.
- If there were a possibility that the cause of death might be an ECG disturbance (which would not be picked up at autopsy) or secondary drowning, then the classification of post-rescue collapse was not made.

Results

In 27 years, there were 89 immersion accidents in the fishing industry. One hundred and twenty-two males and eight females died (Table 1, available as Supplementary data at Occupational Medicine Online). Ages ranged from 19 to 69 years and experience in the fishing industry ranged from none to 45 years. Ten of the fishermen (7.7%) were swimmers, eight (6.2%) could not swim and swimming capability was unknown for 112 victims (86.1%). Clothing worn at the time of the accident was classified as light for seven victims (5.4%), medium for 10 victims (7.7%), heavy for six victims (4.6%) and unknown for 107 victims (82.3%).
Vessel size was reported as under 15 m (34 accidents, 38.2%), over 15 m (16 accidents, 18%), not stated (34 accidents, 38.2%), or not applicable (5 accidents, 5.6%), (e.g. being swept from the shoreline into the sea while harvesting fish). Forty-three accidents (48.3%) were witnessed, and alcohol was reported in the original investigation as a factor in 16 deaths (12.3%).

The accident investigators had classified the accidents as man overboard or suspected man overboard, (33 accidents, 37.1%), suspected sinking or capsizing (38 accidents, 42.7%), groundings (nine accidents, 10.1%) and other or unknown causes (nine accidents, 10.1%). Thirty-seven accidents (41.6%) occurred during daylight and 38 (42.7%) in the dark. Time of day was not known in 14 accidents (15.7%). With the exception of January, when very little fishing occurs, accidents occurred randomly throughout the year.

Water temperature was recorded in 15 (16.8%) accidents, calculated from weather charts in 67 (75.3%) accidents, and estimated in seven (7.9%) accidents (Table 1). The coldest water was 0°C and the warmest was 17.5°C. Only seven temperatures were above 15°C. Water conditions were calm or good in 20 (22.5%) accidents, average in seven (7.8%) accidents, poor or rough in 25 (28.1%) accidents and not stated in 37 (41.6%) accidents. Weather conditions were considered good in 13 (14.6%) accidents, average in 10 (11.2%) accidents, poor in 21 (23.6%) accidents and unknown in 45 (50.6%) accidents.

Flotation devices or immersion suits were carried on board in 28 (31.5%) accidents, not carried in five (5.6%) accidents and unknown in 56 (62.9%) accidents. Flotation devices were worn by 10 (7.7%) victims, immersion suits were worn by 10 (7.7%) victims, no flotation devices were worn by 70 (53.8%) victims and unknown for 40 (30.8%) victims. It was not recorded whether the 10 victims who wore immersion suits wore flotation devices.

The coroners’ reports classified the 130 deaths into three categories (Table 2). After reviewing all 130 deaths, it was possible to assign an underlying cause for the drowning (Table 2). Ninety-four deaths (72.2%) did not contain sufficient information to add to the original death certification. In only four deaths (3.1%) was body-core temperature recorded. In one accident, the victims had body-core temperatures of 25.5°C and 28.9°C and the other temperatures were 35°C and 27°C.

An example of cold shock, swimming failure, hypothermia and post-rescue collapse is briefly described in Box 1.

### Discussion

In our study of 130 deaths, we were able to establish the likely cause of death beyond drowning in 28% of cases only; in the remaining 94 deaths, there were not enough data to draw any conclusions. The study noted that at all levels of the investigation (marine investigator, coroner and pathologist) there was little understanding of cold-water physiology. Each accident report contained many pages related to marine items such as navigation aids, ship’s structure and stability, yet only a single paragraph or sentence related to the death and the survival equipment worn or carried on board. As a result, there was a considerable amount of fundamental data missing (e.g. swimming capability, water temperature, weather conditions, body-core temperature, clothing worn, previous medical history, whether personal

### Table 2. Underlying cause of drowning

<table>
<thead>
<tr>
<th>Classification</th>
<th>Coroner’s classification</th>
<th>Authors’ reclassification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold shock</td>
<td>0</td>
<td>7 (5.4%)</td>
</tr>
<tr>
<td>Swimming failure</td>
<td>0</td>
<td>7 (5.4%)</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>15 (11.5%)</td>
<td>7 (5.4%)</td>
</tr>
<tr>
<td>Post-rescue collapse</td>
<td>0</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>Cardiac event after immersion</td>
<td>2 (1.5%)</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>Drowning or drowning/other</td>
<td>113 (87.0%)</td>
<td>13 (10.0%)</td>
</tr>
<tr>
<td>Not enough information</td>
<td>0</td>
<td>94 (72.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>130 (100%)</td>
<td>130 (100%)</td>
</tr>
</tbody>
</table>

#### Box 1

**Cold shock (7 deaths)**

While setting single pot crab traps, the hauler-operator was pulled into the water when the crab pot line became entangled in the propeller. The victim was in the water for 5 min before becoming unconscious. He was pulled aboard 11 min after immersion, but attempts to revive him were unsuccessful. (November, water temperature 7°C)

**Swimming failure (7 deaths)**

While tossing the ship’s anchor from a skiff, the skipper fell overboard. He then proceeded to swim to shore. A witness from the shore said when he began swimming he was out of the water at shoulder height and the last time the witness saw him before he went under water, the skipper’s chin was barely out of the water. (June, water temperature 8°C)

**Hypothermia (7 deaths)**

One victim fell overboard while setting traps. The second victim entered the water to rescue the first, and was eventually pulled into the boat by the third crewmember after at least a half hour of immersion. Upon admission to hospital, the victims’ body-core temperatures were recorded as 25.5°C and 28.9°C respectively. (June, water temperature 12.2°C)

**Post-rescue collapse (1 death)**

The victim was trapped in the vessel as it sank, but was removed through a broken window. He was transferred to another fishing vessel and CPR was performed. He revived, showed signs of good recovery and shortly thereafter, suddenly died. (August, water temperature 17°C)
flotation devices were worn or not, etc.). Even though there are gaps in the data, they provided a rich snapshot of what has happened over the last 27 years to fishermen who for whatever reason found themselves suddenly and unexpectedly immersed in water.

The majority of drownings (95%) occurred in water below 15°C, which supports the data of Molnar [3] and McCance et al. [5] that sudden, unprotected immersion in cold water below 15°C is potentially very dangerous; and suggest that cold shock and swimming failure play at least as important a part in the cause of drowning as hypothermia. As Golden and Tipton [10] pointed out, most predictions of survival time ignore the first two stages of immersion. This emphasizes the importance of wearing a flotation device to keep the oronasal cavity clear of the water immediately after entry into the water, when an inspiratory gasp, a 4-fold increase in pulmonary ventilation and inability to breath hold is to be expected. It further emphasizes the importance of educating fishermen of the dangers of sudden immersion in water below 15°C and the need for them to attend a survival course.

In order that the correct information will be collected in the future, corrective action has already been taken. Copies of the Transport Canada guidelines on Survival in Cold Waters [11] have been issued to coroners, accident investigators and pathologists. Lectures have been given to the chief coroner and the WCB and a common checklist has been provided for all those involved in the investigation of any immersion accidents (see the Annex, available as Supplementary data at Occupational Medicine Online). Finally, the FAO/ILO/IMO Code of Safety for Fishermen and Fishing Vessels [9] will be amended in 2005 to include the problems of the first two stages of sudden immersion in cold water.

Common sense would suggest that swimming ability, wearing of flotation devices and immersion suits in the fishing industry would save lives. Unfortunately, there were not enough data available to make firm recommendations. It is hoped that with the new checklist, the next review will provide evidence for this.

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Conflicts of interest

None declared.

References

7. Smith FE. Survival at Sea. MRC Royal Navy Personnel Committee. SS1/76.