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# Fatal hypothermia: an analysis from a sub-arctic region

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**Objectives.** To determine the incidence as well as contributing factors to fatal hypothermia.

**Study design.** Retrospective, registry-based analysis.

**Methods.** Cases of fatal hypothermia were identified in the database of the National Board of Forensic Medicine for the 4 northernmost counties of Sweden and for the study period 1992–2008. Police reports, medical records and autopsy protocols were studied.

**Results.** A total of 207 cases of fatal hypothermia were noted during the study period, giving an annual incidence of 1.35 per 100,000 inhabitants. Seventy-two percent occurred in rural areas, and 93% outdoors. Many (40%) were found within approximately 100 meters of a building. The majority (75%) occurred during the colder season (October to March). Some degree of paradoxical undressing was documented in 30%. Ethanol was detected in femoral vein blood in 43% of the victims. Contributing co-morbidity was common and included heart disease, earlier stroke, dementia, psychiatric disease, alcoholism, and recent trauma.

**Conclusions.** With the identification of groups at high risk for fatal hypothermia, it should be possible to reduce risk through thoughtful interventions, particularly related to the highest risk subjects (rural, living alone, alcohol-imbibing, and psychiatric diagnosis-carrying) citizens.

Keywords: *accidental hypothermia; fatal outcome; autopsy*

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Accidental hypothermia as cause of death should be to some extent preventable. While many associated risk factors have been described (1), it is possible that there are regional, climatic, as well as socioeconomic factors in today's society which could lead to a changing pattern for accidental hypothermia in sub-arctic regions. There is a perception that the risk for hypothermia is higher in colder climates and in sparsely populated regions (2,3), possibly due to lower environmental temperatures which would contribute significantly to injury and death, though hypothermia and cold injury can occur in a wide range of environmental temperatures. This includes in water at temperatures below 33°C and in the air at temperatures below 25°C, and even at other temperatures where heat loss from the skin to the environment is possible, including, for example, laying on the ground where conductive heat loss increases. Acute incapacitation, through drugs or acute illness, is thought to be the most important

risk factor for fatal hypothermia (4). Chronic illness and debilitation have been recognized as strong contributing factors to fatal accidental hypothermia, especially in the elderly (1). As society changes over time, the risk for fatal hypothermia may change. Perceived risk for fatal hypothermia in healthy individuals may be small. On the other hand, a large elderly and debilitated segment of the population might lead to increased risk.

The incidence of fatal hypothermia may be under-reported in national registries where choices must be made between multiple diagnoses. The best possible data concerning fatal hypothermia is a prerequisite for national and regional policies and routines designed to prevent fatal hypothermia. We aimed to measure the current incidence of fatal hypothermia as indicated by the forensic medical database for the northern region of Sweden, as well as to assess all available findings for a large regional fatal hypothermia cohort in our sub-arctic

region to try to identify patterns in the circumstances of death and post-mortem findings.

## Materials and methods

All cases where hypothermia was recorded as the underlying cause of death or contributing cause of death in the post-mortem report (according to the reporting routine for the World Health Organization, <http://www.who.int/healthinfo/statistics/mortdata/en/index.html>), were identified in the database of the National Board of Forensic Medicine in Sweden. This was done with the Board's specific permission and consistent with the Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects, 1964. These database records were reviewed and analyzed by the coauthors for the 4 northernmost Swedish counties, geographically 55% of Sweden with approximately 900,000 inhabitants (10% of the nation's total population), for the years 1992–2008.

Outside environmental temperature at the site of death were taken from the included police report. All autopsy and police report information was then collated where cases were identified by cohort number in the series with no personal identifying information. If not reported, the average outdoor temperature for the day on which the victims were reported missing or presumed dead was noted from the records of the Swedish Meteorological and Hydrological Institute. The distance over which undressing prior to death appeared to have occurred was noted when available.

## Definitions

“Urban” was defined as a place or city with a population of more than 3,000 local inhabitants, and “rural” a place with less than 3,000 inhabitants (5). Alcoholism or active drug abuse was defined as a diagnosis obtained from medical records or from the autopsy records. Medical co-morbidity was identified from the same records. “Paradoxical undressing” was defined as an irrational form of behaviour where a cold-exposed person has undressed as a pre terminal event (6). Since paradoxical undressing can take on many practical forms, we grouped the observations to 3 categories: (a) shoes off, (b) upper body undressed, and (c) lower body undressed.

## Analysis

Testing for differences between groups was performed using paired t-test for paired numerical results, and independent samples for comparison of factors where one was categorical and the other was numerical. A p-value <0.05 was considered significant for differences.

## Results

### General

A total of 207 cases were included for analysis. Of these, 149 (72%) were men and 58 (28%) were women. The ages

ranged from 16 to 101 years, with mean age for all victims of  $62 \pm 17$  (mean  $\pm$  SD), for men  $61 \pm 16$ , and for women  $65 \pm 17$  years (Fig. 1).

### Temporal

The average annual incidence of fatal hypothermia for the Northern region during the study period was 1.35 deaths per 100,000 inhabitants.

### Geographical and environmental

The majority of the deaths (150 cases, 72%) occurred in rural areas, while 57 (28%) occurred in urban areas. Since the rural population in northern Sweden is approximated at 144,000 inhabitants (or 16% of the population) (5), this means that the annual incidence of fatal hypothermia in the rural region during this period was 6.1/100,000 inhabitants. With an urban population in this region estimated to be 756,000 inhabitants, the annual incidence of fatal hypothermia in the urban population was 0.4/100,000 urban inhabitants.

There was no difference in age between the urban and rural groups. In 192 cases (93%), the deceased was found outdoors and most of these close to their homes, and in 15 cases (7%) indoors, mixed, heated and unheated shelter at discovery, with no consistent data for “indoor” temperature at time of death. In 53 cases, the body was found in a radius of 5 meters from a house or building, for 11 cases within 5–50 meters, for 8 cases within 50–100 meters, and for 9 cases within 100–500 meters from the nearest building. The remaining 111 victims found outdoors were found more than 500 meters from any building. Deaths for 154 (75%, with total  $n=206$ ) occurred during the cold season, October through March, where the average monthly temperature is less than 10°C (Fig. 2), while 52 (25%) occurred in April through September. For 1 case (1/207), no clear season could be identified. The ambient temperature at

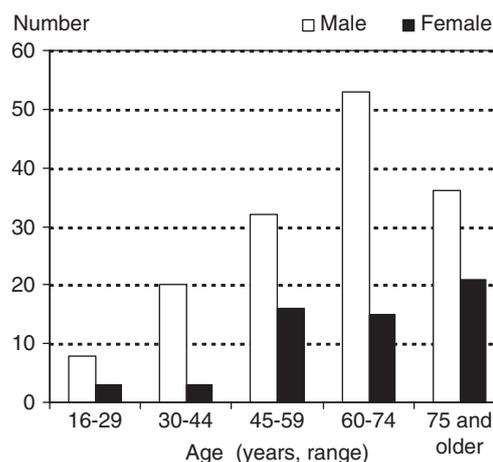


Fig. 1. Age and gender. Ages grouped in intervals, together with gender, show the distribution in this cohort.

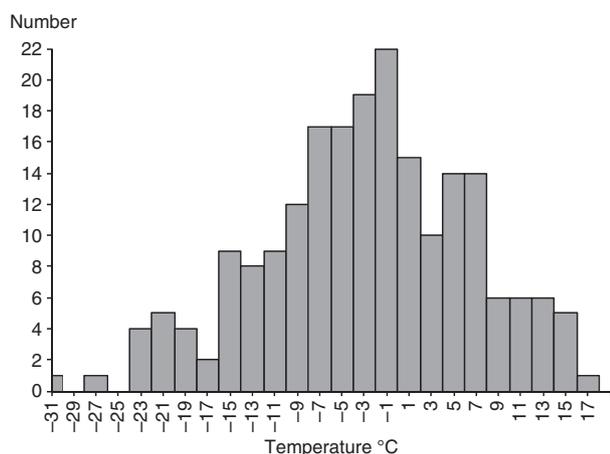


Fig. 2. Environmental temperature day averages for fatal hypothermia events. For the total number of cases (total  $n = 206$ ) where the date of death could be established, the local temperature intervals are presented together with number of cases at that temperature interval.

the time of exposure was recorded in the police report for 48 (23%) of the cases, and was unrecorded in 159 cases (77%). Average outdoor temperatures for the recorded day of death were for 75 (36%) above  $0^{\circ}\text{C}$ , for 88 (43%) from 0 down to (but not including)  $-10^{\circ}\text{C}$ , for 32 (16%) from  $-10^{\circ}\text{C}$  down to (but not including)  $-20^{\circ}\text{C}$ , and for 11 (5%), the temperature  $-20^{\circ}\text{C}$  or below (Fig. 1). Fifty five (27%) of the cases were exposed to water, having either broken through ice, fallen out of a boat or chosen to use cold water as a suicidal means. Forty nine of these were immersed partly or completely, although with their mouth or nose still above surface, while 6 were fully submersed (mouth and nose under water) when found.

#### Ante-mortem

Some degree of paradoxical undressing was documented in 63 of 207 (30%) cases, while the rest were found fully clothed. Thirty nine had taken off 1 or both shoes, 33 had disrobed their upper body, and 23 had disrobed their lower body, with 26 presenting a combination, with 4 disrobing by all categories. The combination of undressing and distance from final resting place is shown in Table I.

Table II. Post-mortem anatomical findings

	Not known	Not present	Present minimal	Present moderate	Present severe
Excoriations	5	69	114	9	10
Gastric erosion	0	71	47	28	61
Fatty infiltrate of the liver	0	95	56	33	23
Pancreatitis	1	204	2	0	0
Coronary artery disease	1	74	59	35	38
Cardiomyopathy	2	188	15	1	1

Table I. Type and location of paradoxical undressing

Distance from final site (m)	Total number	Upper body	Lower body	Shoes
0	46	21	18	24
0–5	9	3	0	8
6–10	3	3	1	2
11–15	1	1	0	1
16–20	1	2	1	1
21–25	0	0	0	0
26–30	1	1	1	1
>30	2	2	1	2

Note: Paradoxical undressing  $n = 63$  out of 207 total cases. The distance indicates where clothing item was found in relation to the final resting place of the victim.

Sex, mean age, body-mass index, and alcohol presence all showed no relation to paradoxical undressing.

#### Post-mortem

The most common post mortem findings included, excoriations – particularly on the hands and forearms, gastric erosions, coronary artery disease, and fatty infiltration of the liver (Table II). Pancreatitis was infrequent. The mean heart weight was for men  $440 \pm 104$  SD g ( $n = 148$ ), and for women  $350 \pm 113$  g ( $n = 48$ ). The mean weight of the lungs (7,8) was  $1077 \text{ g} \pm 313$  ( $n = 148$ ) for men, and  $829 \pm 304$  g ( $n = 51$ ) for women.

Ethanol was detected in femoral vein blood samples from 90/207 (43%) of the cases; of these 57 were identified as alcoholics. The mean concentration of ethanol for cases testing positive in both blood and in urine ( $n = 81$ ) was for blood  $1.56 \pm 0.92$  g/L, and for urine  $2.53 \pm 1.23$  g/L (Fig. 3). The urine ethanol concentration was significantly higher than the blood ethanol concentration ( $p < 0.001$ ). Cases involving alcohol occurred with the same relative frequency in rural areas ( $n = 65/150$ , or 43%) as in urban areas ( $n = 25/57$ , or 44%). In 50 cases, drugs other than alcohol were detected in femoral blood samples. The most common were benzodiazepines ( $n = 17/50$ , 34%), major sedatives and anti-depressives ( $n = 14/50$ , 28%), amphetamine ( $n = 9/50$ , 18%), opiates (7/50, 14%), cannabis ( $n = 4/50$ , 8%), and antiepileptics

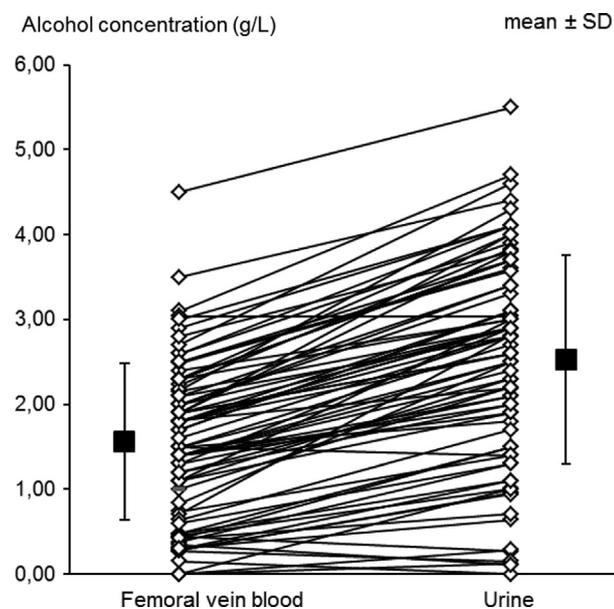


Fig. 3. Alcohol levels in blood and urine. The mean value ( $n = 81$ ) for blood ( $1.56 \pm 0.92$  g/L) was lower than that in urine ( $2.53 \pm 1.23$  g/L, paired t test).

(5/50, 10%). In only 1 case was a very high blood concentration of an illicit drug (amphetamine) detected.

Co-morbidities in this cohort (207) include coronary artery disease ( $n = 67$ , or 32%), previous stroke ( $n = 13$ , 6%), recent pneumonia ( $n = 3$ , 1%), dementia ( $n = 31$ , 15%), epilepsy ( $n = 8$ , 4%), psychiatric disease ( $n = 29$ , 14%), and alcoholism ( $n = 72$ , 35%). There were a total of 18 cases where some form of injury (old or recent) was noted in the post-mortem report. In 8 cases (4%), trauma was named in the post-mortem report as a finding at autopsy and/or as a contributing factor for death by hypothermia.

In 25/207 (12%) of the cases, hypothermia was given as a secondary cause of death, with primary diagnosis offered as “multiple organ failure” ( $n = 6$ ), heart disease ( $n = 14$ ), pneumonia ( $n = 1$ ), recent closed head injury ( $n = 1$ ), drowning ( $n = 2$ ), and unknown ( $n = 1$ , advanced decomposition). Suicide was suspected in 11/207, based on corroborative information from the police report and/or medical records. Pre-morbid activities were snowmobiling ( $n = 13$ ), skiing ( $n = 6$ ), walking/hiking ( $n = 61$ ), fishing ( $n = 6$ ), walking on ice-covered water ( $n = 5$ ), and driving/car ( $n = 4$ ). For the rest ( $n = 113$ ), there was no obvious or particular pre-mortem activity which was noted in the police report.

## Discussion

### General and temporal

We have presented an analysis of important aspects of fatal hypothermia in a sub-arctic region in Northern

Sweden from 1992 to 2008. The main finding was that the incidence of fatal hypothermia is 1.35/100,000, which is nearly double than reported in previous reports, from the same region or similar regions (4,9–11). Possible reasons for this difference are that the number of elderly has increased (12), and in recent years, it is more common in Sweden that older people with dementia live at home rather than in nursing homes (13). Our findings support the idea that there are few younger and healthy inhabitants who succumb to fatal hypothermia, at least compared to an earlier report (4) from the same region.

### Geographical and environmental

The higher relative incidence of fatal hypothermia occurs in rural areas, despite the fact that the vast majority of the population in our sub-arctic region live in urban areas confirms a strong association between rural living and fatal hypothermia. Sweden, together with Finland, is the most sparsely populated countries in Europe, with approximately 22 inhabitants/km<sup>2</sup> (5). The land area for the region from which this cohort was gathered is largely rural, and the greater part of the population lives in coastal cities. The Swedish governmental description of the rural vs. urban context includes a third category of “non-urban but moderately populated region near an urban area”, and in this report, this category has been analysed as rural.

Even in rural areas, a large proportion (81/207) of events occurred within close proximity to other people and buildings. There is a limited time period where hypothermic individuals can be found and resuscitated, however presumably, there is a time interval while hypothermia begins and before body core temperature and function decrease, during which there is a (even if brief) period of consciousness where a signal for help (if readily available) could be made. This suggests that if individuals are identified early on as missing and at risk for hypothermia, an early search in the local vicinity might save lives.

In a large number of cases (81/207), the victim was discovered within 500 meters of an occupied building, usually close to their home. Earlier reports from the same region have not included this aspect (4,6). This new information confirms the established and current international police and rescue emergency search strategy when there is an alarm for a missing person in a cold environment, which presumes that the victim is not far from the inhabited area. The most important element is that there is an early alarm for a missing person and that the search is initiated immediately. A likely common social aspect for many fatal hypothermia victims is that they do not reside in company; hence the police are not alerted early on. Our study design did not include an assessment of “near misses” or cases where

fatal hypothermia was near, where a well-timed search and rescue succeeded. This can be the subject for a future study.

In more than one third of the cases, the outdoor/ambient temperature was above freezing point, a finding which differs from an earlier report from the same region (4). This finding is a reminder that also temperatures above freezing can be critical. There was a strong seasonal distribution, with higher incidence in the colder periods, which agrees also with a previous report of urban hypothermic deaths (9).

More than one quarter of victims were exposed to water in connection with their hypothermia incident. Immersion is widely recognized a strong risk for hypothermia (14–16). As part of an educational program, the public should appreciate the threat of hypothermia even above freezing temperatures, as well as the very high risk of hypothermia related to immersion in a cold environment.

There was a significant daily variation in temperature, so mean daily temperatures were used here. The exact temperature may not be all that important since it is clear that victims can succumb quite readily even in above freezing temperatures. One additional aspect to consider might be the contribution of wind and humidity to cooling in subjects exposed to hypothermia, but this was not addressed in our study.

#### ***Ante-mortem***

Paradoxical undressing was documented in approximately 1/3 of the cases, and these observations correspond with a previously report (6). It occurred both below and above 0°C, and there was no relation between the incidence of undressing and the ambient temperature, drug blood concentrations after death or any other factor. The cause of paradoxical undressing may in part be due to a combination of vasodilatation with consequent skin-warming, and diminished mental capacity, both of which may occur as central cooling proceeds (6). Mechanisms for vasodilatation itself include either alterations in central autonomic control over the arterioles or decrease in function of peripheral nerves or paralysis of local vascular musculature. Vasodilatory phenomena during hypothermia are recognised as part of reflex mechanisms to try to rewarm the extremities and prevent cold injury (17,18). The role of vasodilatation in paradoxical undressing has, however, not yet been clearly demonstrated (2). One can speculate that a sudden opening of previously constricted peripheral vessels could induce a sense of warmth, and, hence, a desire to undress. Undressing and vasodilatation would without doubt accelerate heat loss and rate of core cooling.

A majority of cases did not remove all their garments, but most often just the shoes. When clothes were removed, they were usually found very close to the body. Complete or almost complete undressing is thought to be very rare. An earlier series (19) described 69 fatal hypothermia cases where 25% demonstrated paradoxical undressing, and the majority of these started with disrobing of the lower body, a finding corroborated by us. Removal of shoes in high frequency has not been reported in this context previously. The observation that clothes were usually found close to the body may indicate that disrobing was possible during the period of last coordinated physical activity before unconsciousness and death. Still, we and others report findings of victims who have taken off their shoes, walked some distance, and then undressed before succumbing. These results demonstrate that there was a dynamic disrobing process while the victims were still somewhat mobile which supports the idea that a profound systemic vasodilatation does not occur in connection with paradoxical undressing, since this would have caused significant hypotension and shock.

#### ***Post-mortem***

Pancreatitis has been reported to be strongly associated with hypothermia and death (20,21) even unrelated to alcohol consumption (22). Pancreatitis was infrequent (only 2 cases) in our cohort, although systematic histological examinations were not performed on macroscopically normal organs. These data suggest that the association between fatal hypothermia and pancreatitis may have been overestimated in earlier previously reported smaller series, or alternatively, that the different cohorts are sampling different populations with regard to pancreatitis risk.

It is likely that acute alcohol intoxication contributes significantly to the risk for fatal hypothermia, since a large proportion here demonstrated recent alcohol intake. The relative incidence of test positive victims here (43%) was, however, lower than the approximately 2/3 previously reported (4). In this cohort, high concentrations of drugs was uncommon, despite the general appreciation that drug use and side-effects, particularly in the elderly has increased in recent years (23). There were higher levels of alcohol in urine than in blood (24) supporting the idea that the victims were in the active blood-alcohol filtration phase, indicating that alcohol intake had not occurred immediately before death.

Coronary artery disease, alcohol use, dementia and other psychiatric illness were the strongest risk factors of death. Psychiatric illness or dementia was noted for almost 1/3 of the fatal hypothermia cohort, confirming

previous reports (1) which have described risk for people with chronic disability and poor insight into their illness. Relatively few in this series were healthy individuals involved in outdoor sporting activities, which supports the idea that sports in cold weather do not seem to present a prominent risk factor for fatal hypothermia.

The incidence of fatal hypothermia may be under- or over-estimated in different registries due to failure to capture the correct cause of death. Even in Sweden, the incidence of reported deaths registered under this category is far lower than what we observed in our cohort (approximately 0.5 vs. 1.5 hypothermia deaths per 100,000 inhabitants) (25). Despite Sweden covering a large geographic area there is not a significant variation in climatic zones for the populated areas, and therefore we see no reason to believe that there should be a substantial regional variation in hypothermia deaths within the country. There may be some variation in hypothermic death incidence for different sub-arctic regions around the world, possible related to socio-economic conditions.

#### **Implications of these findings**

Educational efforts that lead to increased awareness of risk factors, particularly in families or social groups, to influence health risks related to alcohol abuse have been limited to date. Persons with limited or no insight into their own hypothermia risk (alcoholics, psychiatric illnesses, including dementia) need to be better recognized among caregivers, since this group still constitutes the largest number of fatal hypothermia victims. Given the general access to mobile telephones, it seems that either increased awareness of the risk, increased supervision of those who do not command awareness, and some adaptation of existing technology to allow simple local signalling for help probably could save lives when hypothermia risk is present.

#### **Summary and conclusions**

We noted a high annual incidence (1.35 per 100,000 inhabitants) of fatal hypothermia in Northern Sweden. Factors associated with fatal hypothermia were alcohol intoxication paradoxical undressing, proximity to inhabited areas, whereas pancreatitis was uncommon. We conclude that, with the identification of groups at high risk for fatal hypothermia, it should be possible to reduce risk through thoughtful interventions, particularly related to the highest risk subjects: rural, alcohol-imbibing, and psychiatric diagnosis-carrying citizens.

#### **Conflict of interest and funding**

No authors have any conflict of interest to declare in connection with this material.

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