Web-based hypothermia information: a critical assessment of Internet resources and a comparison to peer-reviewed literature

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Abstract

Aims: Hypothermia is a medical condition characterized by a drop in core body temperature, and it is a considerable source of winter weather-related vulnerability in mid-/high-latitude areas. Heat vulnerability research, including assessments of internet-based resources, is more thoroughly represented in the peer-reviewed literature than cold-related vulnerability research. This study was undertaken to summarize available web-based hypothermia information, and then determine its scientific validity compared to the peer-reviewed literature.

Methods: This research takes a similar approach used by Hajat *et al.* for web-based heat vulnerability research, and utilizes this framework to assess hypothermia information found on the internet. Hypothermia-related search terms were used to obtain websites containing hypothermia information, and PubMed (medical literature search engine) and Google Scholar were used to identify peer-reviewed hypothermia literature. The internet information was aggregated into categories (vulnerable populations, symptoms, prevention), which were then compared to the hypothermia literature to determine the scientific validity of the web-based guidance. The internet information was assigned a Strength of Recommendation Taxonomy (SORT) grade (developed by the American Academy of Family Practitioners) of A, B, or C based on the peer-reviewed evidence.

Results: Overall, 25 different pieces of guidance within the three categories were identified on 49 websites. Guidance concerning hypothermia symptoms most frequently appeared on websites, with six symptoms appearing on 50% or greater of websites. No piece of guidance within the vulnerable population categories appeared on greater than 60% of the websites, and prevention-related guidance was characterized by varied SORT grades.

Conclusions: Hypothermia information on the internet was not entirely congruent with the information within the peer-reviewed medical literature. Several suggestions for improving web-based hypothermia resources include clearly listing sources for users to see and eliminating guidance with lower SORT grades and replacing with evidence-based information.

INTRODUCTION

Hypothermia is a drop in core body temperature below 35°C caused by exposure to cold air, immersion in cold water, or from thermoregulation inefficiencies attributable to senescence or underlying illness.[1–4] Prominent hypothermia symptoms include shivering, cardiovascular irregularities, and a reduction in mental and physical capabilities.[1–3,5,6] Hypothermia progresses through three stages: mild, moderate,

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and severe (see online supplementary Table 1). Hypothermia is a significant cause of winter season morbidity and mortality in middle and high-latitude regions.[7–11]

There is much hypothermia-related information on the internet, but its scientific validity has not been assessed. This research took a similar approach to a heat vulnerability review conducted by Hajat *et al.*[12] and analyzed the content of web pages containing hypothermia-related information. Websites were identified using Google searches and were reviewed for suitability. The guidance within the websites was aggregated into categories (vulnerable populations, symptoms, prevention), and the percentage of websites that contained each piece of guidance was calculated. The guidance was then compared to peer-reviewed hypothermia literature to determine its scientific validity. It should be noted that this study exclusively assessed direct cold exposure hypothermia, and it did not analyze excess cold morbidity and mortality related ailments such as cardiovascular disease.

This research is important for a number of reasons. As hypothermia is a considerable source of winter-time morbidity and mortality, it is imperative that the best information be available to internet users. Also, medical practitioners can use this research to guide their patients to additional information that is scientifically sound. Hypothermia guidance sections on websites can be redeveloped to more accurately reflect the peer-reviewed literature, allowing users to better prevent hypothermia morbidity and mortality. Evidence-based symptom information will allow users to better identify hypothermia in others. Additionally, weather forecast offices that regularly issue warnings for dangerous cold can include links to websites with valid hypothermia information for those living within their forecast area.

METHODS

A search strategy and website selection criteria were applied in a manner similar to Hajat *et al.*[12] The Google search engine was used to search for websites with hypothermia-related information using several search terms, which were 'hypothermia', 'hypothermia treatment', and 'hypothermia and public health department'. Preliminary research using Google Trends indicated that these terms were commonly used to search for hypothermia information. Also, we were trying to emulate the search pattern used by lay people when searching for hypothermia information. The first 10 pages of results were searched for usable websites; typically, after five pages, many repeat results were returned. The redundancy of the results makes the list of websites robust, so that it accounts for variability in search results.

Several exclusionary criteria were applied to eliminate websites with potentially biased or unusable information. The first criterion was that the website could not be an advertisement. As many websites were company web pages dedicated to selling hypothermia prevention products, with guidance centered on the use of the advertised product, these sites were eliminated from analysis. The second exclusionary criterion was that the website was not to be video-centric, such as YouTube; many results on these websites were not related to medical hypothermia. The third criterion was that PDF and text document results had to have an associated web page; those not associated with an active website or those with broken web links were not assessed because it was impossible to determine document authorship. The last exclusionary criterion was simply eliminating results that contained no information relevant to hypothermia. Of 139 websites identified, 49 met all inclusion criteria (online supplementary Table 2), and several types of websites were identified in this process. Popular (n = 14) websites were associated with a variety of institutions and wrote about hypothermia in simpler, less formal terms and were tailored for broader audiences. Medical[13] websites were associated with medical institutions and public health departments, and featured more technical discussions on hypothermia. Outdoor[10] websites were written for audiences engaged in outdoor activities such as hunting, fishing, and hiking, and were strongly focused on preventing hypothermia. Special group[1] websites did not fit into the previous categories and presented hypothermia information to specialized audiences. The hypothermia information within the websites was placed into one of the following categories:

- Populations of increased hypothermia vulnerability (vulnerable populations);
- Symptoms of hypothermia (symptoms);
- Hypothermia risk mitigation measures (prevention).

The information was coded so the guidance could be tallied, and then the percentage of websites, including the information, was calculated. Initially, there were categories for causes and treatments. The cause category was eliminated because it dealt with the medical definition of hypothermia, and most websites did not elaborate more than 'hypothermia is caused by cold exposure'. The treatment category was eliminated because of a paucity of peer-reviewed literature concerning the efficacy of hypothermia field treatment methods, such as use of blankets, drinking warm liquids, and other hypothermia management methods.

The hypothermia literature was reviewed to determine the stated guidance's scientific validity. PubMed, a search engine for medical literature, and Google Scholar were searched for hypothermia articles using various search terms (online supplementary Table 3). A larger number of search terms were utilized here compared to the Google searches so medical articles directly addressing the website guidance could be identified. Articles were reviewed for suitability, with a total of 58 peer-reviewed articles identified during this process.

The website guidance was then graded using the Strength of Recommendation Taxonomy (SORT), a criteria scale developed by the American Academy of Family Practitioners. These grades rated the website guidance's congruence to the peer-reviewed literature. This ranking method was employed

on a position statement issued by the American College of Sports Medicine in a report on cold weather injury and exercise.[14,15] This scale utilizes grade rankings of A, B, and C to evaluate the scientific validity of the guidance. An A grade indicates that the guidance is based on consistent and good patient-based scientific evidence. A B grade indicates that there is some scientific evidence, but it is of limited quantity and lower quality. A rank of a C indicates that evidence is based on consensus, opinion, or usual practice.

RESULTS

Overall, 25 facets of hypothermia guidance from the three categories of web-based hypothermia information were assessed (online supplementary Table 4). There are four categories of SORT grades included in the table: Science, Epidemiology, Usefulness, and Usability. The Science grade reflects the medical and physiological evidence for a specific piece of guidance. The Epidemiology category refers to the evidence regarding the vulnerability of specific populations to hypothermia, and is only applicable to the vulnerable populations category. The Usability grade assesses how well a specific symptom indicates the presence of hypothermia, while the Usefulness grade evaluates how early in the course of hypothermia the symptom occurs. The effects of hypothermia are less reversible later in the course of hypothermia, and symptoms that occur later are accordingly graded lower.

Vulnerable populations

For vulnerable populations, two SORT grades are provided: one assessing the medical evidence and the other assessing the epidemiological evidence. The most frequently listed vulnerable population was the elderly (Science and Epidemiology SORT grade of A), which appeared on 59% of the websites assessed. Several factors contribute to the high level of elderly hypothermia vulnerability. First, the cold response mechanism becomes less efficient with age.[3,16,17] Second, actual temperature sensation of the cold becomes blunted as people age.[4,18,19] Therefore, ambient conditions are not perceived to be cold. Additionally, many elderly have a smaller body mass index (BMI) than middle-aged adults. Smaller bodies lose radiative heat more quickly than larger bodies, and many elderly people have less subcutaneous fat providing insulation against the cold because of malnutrition.[19] However, a study by DeGroot *et al.*[20] found weak evidence for body fat as a predictor of elderly hypothermia. Age-related mental decline also contributes to their vulnerability.[19] Epidemiological data demonstrate that the elderly have higher rates of both morbidity and mortality compared to other age groups.[7,8,11,21,22] Additionally, there is the social confounder of isolated living that contributes to their vulnerability.[19]

Small children (A, C) were listed as a vulnerable population on 47% of the websites. Small children and infants can lose much heat to the surrounding environment because of a high surface area relative to their overall mass, which hypothetically increases their hypothermia vulnerability.[1,13] However, epidemiological evidence suggests that this age group is less vulnerable to hypothermia, with low overall death rates compared to older age groups.[7,11,23] Baumgartner *et al.*[24] conducted an analysis of hypothermia morbidity from a small sample of US hospital data, and found that persons under the age of 15 were approximately 5% of the sample.

Alcohol abusers (A, A) were listed as a vulnerable group on one-third of the websites analyzed. Ethanol acts as a vasodilator that counteracts the body's vasoconstriction reaction to cold.[2,3,25,26] Ethanol can also have a muscle-relaxing effect that hinders shivering thermogenesis.[1,25–27] Additionally, intoxication can act to inhibit shelter-seeking behavior.[1,3] Several retrospective studies have indicated that alcoholics have an increased risk for hypothermia morbidity and mortality.[6,8,22,28–31]

In all, 27% of websites stated that underlying medical conditions (A, B), or taking medicine for other medical issues, increased an individual's susceptibility to hypothermia. There are many medical conditions that can potentially increase one's hypothermia risk.[4,28,32] However, diabetes particularly blunts the cold response through decreased cold sensation.[28] While many of the deaths contained in data sets list underlying causes of death, it is not easy to obtain information about the victim's medication. Therefore, epidemiologic knowledge of hypothermia and medical conditions is incomplete.

Approximately one-quarter of the websites investigated stated the homeless (C, B) are susceptible to hypothermia, as they are dangerously exposed to cold temperatures. Research suggests that sustained cold exposure can lead to a diminished cold response;[14,33] while it is plausible that the cold response can become blunted in the homeless, no studies directly address this. There are also significant confounders with substance abuse, malnutrition, and mental illness in this population.[34] Epidemiological data are difficult to obtain for the homeless; however, Hwang[35] found that homeless shelter users in Toronto were sometimes afflicted with cold weather ailments. Homeless hypothermia decedents are sometimes found outdoors with high blood alcohol concentrations.[9,22,31]

People who spend time outdoors (hikers and workers who willingly spend time outdoors, distinct from homeless; A and B) were also listed as vulnerable to hypothermia (24%). The cold response follows a different course in this population. Initially, core temperature increases with heavy exertion, compensating for increased heat loss potential due to vasodilation. However, when the individual rests, core temperature stops increasing, and the cold response does not immediately begin, which rapidly sends the victim into hypothermia through evaporative cooling.[33,36] Two studies[22,23] indicated that outdoor workers had higher rates of fatalities compared to the average population. However, these studies had small sample sizes and were geographically limited in scope (Jefferson County, AL, USA). These two studies did not examine hypothermia morbidity.

Mental illness (C, B) was purported to increase hypothermia vulnerability on 16% of websites. While mental illnesses do not impact the cold response itself, people with these conditions incorrectly perceive danger levels, and do not implement behavioral changes to reduce hypothermia risk. Lack of behavior changes to a stressor does not constitute medical vulnerability. Additionally, this information is not listed on death certificates, and official counts of hypothermia deaths of mentally ill people are difficult to obtain. *Storm Data* is the official source for storm-related losses in the United States, and it contains information on hypothermia-related deaths. While this publication is known for undercounting storm-related deaths, some hypothermia deaths in this database contained text describing the context in which the fatality occurred. Some descriptions mentioned the victim had a mental illness and had gone into cold ambient conditions.[37] Overall, few epidemiological data demonstrate the hypothermia vulnerability of the mentally ill.

Malnourishment is described in prevention as food and hydration-related guidance (A, C). No studies have examined the relationship between hypothermia fatalities and nutrition status as reported on death certificates.[14,38,39]

Symptoms

Overall, hypothermia symptoms were listed on a higher percentage of websites than the other categories; six of the ten symptoms were identified on 50% or more of the websites. Symptoms have a three-part SORT taxonomy that gauges several aspects of the guidance. First, the scientific evidence is assessed to determine whether the symptom occurs when the victim becomes hypothermic. The second part of the SORT grade is a usability ranking, or how easy it would be to use this symptom as a specific indicator of hypothermia. The last part of the SORT grade is a usefulness rating, that is, does this symptom occur in the early stages of hypothermia, or does this occur when the effects of hypothermia are irreversible?

Shivering (Science SORT grade of A, Usability SORT A, Usefulness SORT A) tied with mental impairment as the most commonly listed symptom on websites (80%). One of the first stages of the cold response, rapid muscle contractions, is capable of raising core body temperature by nearly 2°C per hour with adequate energy intake.[2,3,18] Overall, identifying shivering does not take advanced medical knowledge, and this symptom is also specific to hypothermia. Shivering occurs early during hypothermia (it stops as hypothermia becomes more severe) when the effects are largely reversible.[5,18,40]

Mental impairment (A, B, B) was also listed on 80% of the websites. Successive decreases in core body temperature overwhelm the cold response.[41] As brain temperature decreases, electrical activity begins to slow down due to impaired conduction.[18,41,42] This has a cascading effect on brain function – first conscious thought is affected, followed by systems that are not under conscious control (breathing, heart rate, etc), leading to a wide range of symptoms. Because a wide range of impacts are involved, mental impairment could be a nonspecific symptom based on context, especially if those involved are not outdoor people or if the ambient conditions are not perceived to be dangerous. As a wide variety of conditions cause mental impairment, it is not a clear indicator of hypothermia.

Physical coordination (A, B, B) similarly declines as core temperature decreases, and this was given as a hypothermia symptom on 76% of websites. This is related to the loss of higher mental function and the brain's ability to conduct electrical signals.[41] As higher thought is reduced, the ability to coordinate one's movements decreases and vasoconstriction reduces blood flow to the extremities. There are other ailments that might cause a rapid loss of coordination; however, in the absence of mentally impairing substances, this is a reasonable indicator of hypothermia. Physical coordination issues can occur in mild to moderate hypothermia so has limited usefulness.[1,5]

Incoherence (A, B, B), or the inability to communicate thoughts clearly, was listed as a hypothermia symptom on approximately 60% of the websites. As brain and core temperatures drop, neurons have a reduced ability to conduct electricity, with a concurrent loss in conscious thought that also reduces the ability to communicate clearly.[2,18,41] While this can indicate the presence of other ailments, the ability to communicate is also linked to body language and behavior. Early on in hypothermia, behavioral changes render the victims withdrawn and difficult to communicate with, so it is a reasonable early indicator of hypothermia.[41] If all other factors are known to be equal (the victim is with acquaintances who know the personality of the victim, and it is known no drinking is involved), this can be a clear indicator of hypothermia. However, it can occur in the moderate hypothermia stage, so its usefulness is limited.[1]

Cardio-respiratory problems (A, B, B) were mentioned on 53% of websites. There are many different manifestations of cardiovascular problems of hypothermia. In the initial stages of hypothermia, the heart rate and breathing speed up; as hypothermia becomes more severe, the heart rate begins to slow down, sometimes becoming almost undetectable.[3,18,43] Later stages of hypothermia are associated with electrolyte imbalance; in severe hypothermia, the heart can stop completely.[3,18,41,44] While pulse changes could be detected, heart irregularities are more difficult to judge. Also, in the absence of other symptoms, pulse changes would be insufficient for a field diagnosis of hypothermia. Heart rate changes are well defined by stage of hypothermia, so they are a strong indicator of hypothermia severity to knowledgeable people. However, for most of the population, it is of limited usefulness in determining the presence of hypothermia.

Reduced energy (A, B, C) was listed on 50% of websites. Experiments performed by Young *et al.*[45] demonstrated

that after long-term exertion fatigue, the cold response becomes compromised. Hypothermia victims have reduced energy levels as hypothermia progresses.[41] However, reduced energy or constant fatigue is an underlying symptom in a number of ailments (e.g. cancer, ischemia, multiple sclerosis), limiting its usability in identifying hypothermia.[46–48] Overall, its usability is limited because clear indications of reduced energy occur during moderate and severe hypothermia,[41] and other, more prominent symptoms occur during mild hypothermia.

Other symptoms reported on websites include loss of consciousness (43%), pale/icy skin (29%), and paradoxical undressing (8%). Loss of consciousness occurs in the later stages of hypothermia (A, C, C);[1,41] however, this symptom is a non-specific diagnostic tool because many other ailments are associated with unconsciousness, and it occurs when the victim's survival is less likely. Pale/icy skin (A, B, B), or pallor, refers to the loss of skin color that can occur during hypothermia. This can be concurrent with frostbite and occurs because of reduced blood flow to the extremities and the top layer of skin, making the skin cold to the touch.[40,41] This symptom can be indicative of other ailments, so is not hypothermia-specific. However, it can occur in the early stages of hypothermia, so it does have some diagnostic utility. Paradoxical undressing (B, C, C) is when a victim removes their clothes in the late stages of hypothermia. It is thought that warm blood flowing back to the extremities causes a strong heat sensation, which compels the victim to take off their clothes. This has limited usability and usefulness because paradoxical undressing occurs when the victim's chances of survival are low.

Prevention

Similar to vulnerable populations, only some prevention guidance is mentioned on a high percentage of websites. Approximately three-quarters of websites listed 'wear appropriate clothing in layers' (Science B) as a preventative measure, with 51% of websites also stating to 'cover head/extremities' (Science A). Significant heat loss occurs through the skin, and this is mitigated by wearing additional clothing.[28,49] Heat loss through the head deserves a special explanation, as this specific guidance appeared on many websites. For many years, it was believed that 50% of heat loss occurs through the head, based on flawed early research and a US Military manual.[50,51] Pretorius *et al.*[52] found that heat loss through the head is no greater than in other parts of the body; uncovered areas lose a proportionally large amount of heat. It is difficult to ascertain what 'appropriate' clothing is, and there are a limited number of scientific studies testing the efficacy of various clothing types. In an epidemiological study examining mountain hikers, layered clothing that was alternately removed and added to as activity increased and decreased was the best way to delay the onset of hypothermia.[33,36] A review of exercise practices in the cold demonstrated that a wind and waterproof outer layer, with a moisture-wicking layer near the skin and a thicker, water absorbent middle layer, was a good way to slow hypothermia onset while engaged in physical activity.[14] However, the authors also admitted that it was difficult to give concrete advice with regard to clothing, as individual morphology, and fitness level, played some role in how well subjects resisted the cold. In summary, wearing clothing is paramount to hypothermia prevention, but the exact type of clothing varies based on individual factors. All areas of the body lose heat and need to be covered.

Food- and hydration-related guidance (A) appeared on 43% of websites. Increased food intake is needed to fuel the body's cold response and its associated high basal metabolic rate. Without increased energy intake, the body's cold response becomes impaired; however, if properly clothed and not exercising for long periods, the body's core temperature would be higher than resting level and would require only supplementation from small snacks in addition to regular meals.[14,38,39] Dehydration (C) has no impact on the body's cold response.[14]

'No alcohol, smoking, or caffeine' was offered as prevention guidance on 31% of websites. The effects of alcohol (A) were analyzed in vulnerable populations under alcohol abusers. No research specifically addressed the impacts of smoking (C) on hypothermia. Caffeine (C) has been noted by Sterba[53] and Irwin[54] as a beverage ingredient to avoid because of its diuretic effects. However, as stated earlier, dehydration has no effect on the cold response.[14]

'Stay dry/do not over-exert' (A) was listed on 31% of websites. Water immersion can rapidly cause hypothermia, as water conducts heat 25 times greater than an equivalent volume of air.[6] Moist ambient conditions can also contribute to a core temperature drop through evaporative cooling.[55] Exertion can result in perspiration and fatigue, which can impact the cold response (see 'reduced energy' and 'people who spend time outdoors').

'Avoid cold temperatures and high winds' (A) was given as preventative guidance on 29% of the websites assessed. During prolonged exposure to ambient cold temperatures, the body loses more heat than it produces, and wind exposure lowers core temperature through evaporative cooling (for perspiring individuals) or the wind creating convection near the skin, which disrupts the stable warm air near the skin.[49,55–57] While not capable of cooling the body temperature greatly, the concurrent risk of frostbite makes wind exposure a dangerous phenomenon.[14]

'Not wearing cotton garments' (C) was guidance given on 14% of websites. Some research has attempted to determine the thermal properties of garments in different conditions. Anecdotal evidence states that cotton is a poor insulator when wet, and that wool retains its insulation properties. However, research by Holmer[58] showed that wet wool garments lost some of their thermal properties when wet, and that wet wool retained thermal properties more than wet nylon garments. Navy diving experiments also demonstrated that wool is a poor insulator when wet.[53] Wool has a

high heat of sorption, so it is possible this is perceived as increased warmth by the wearer.[59] Limited research exists on cotton and its thermal properties when wet. A study by Bakkevig and Nielsen[60] showed that wet undergarments (cotton, wool, polypropylene, and a wool mix) significantly contributed to cooling; however, the thickness of the garment was more important than the type of fabric with regard to heat retention. Richards *et al.*[61] also found that total evaporative heat loss was less for cotton compared to polyester and polypropylene.

One website mentioned that it was useful to take time to 'acclimatize to the cold' (C). There are several physiologic mechanisms through which the human body acclimatizes to warm temperatures; in comparison, the body's adaptations to cold are much less robust and are difficult to replicate in a laboratory setting.[14] While some anecdotal evidence suggests that people can adapt to cold temperatures, there is little scientific evidence that suggests humans acclimatize to the cold.

DISCUSSION

This article sought to synthesize available hypothermia information and guidance on the internet and critically compare it to the peer-reviewed literature. This was done because hypothermia information on the internet is widespread, and it has not been assessed for its quality. Overall, 25 pieces of guidance on 49 websites were assessed.

Vulnerable populations were underemphasized on these websites. Additionally, it should be noted that websites do not differentiate between morbidity and mortality for vulnerable populations. The elderly are highly vulnerable to hypothermia, but fewer than 60% of the websites assessed mentioned this. Also, none of the websites identified listed minorities as vulnerable populations. In the United States in particular, ethnic minority groups such as African Americans and Hispanics have higher rates of hypothermia deaths than White people do.[11] While a review of cold-induced finger vasodilatation demonstrated that Black people had the smallest response,[62] the primary driver of this vulnerability is socio-economic disparities.[7,11]

A considerable number of the websites focused on stating the symptoms of hypothermia, and comprehensively listed those that could be identified in the field. Shivering, mental impairment and physical impairment, were stated as hypothermia symptoms on at least three-quarters of the websites utilized. However, loss of consciousness was stated on 43% of the websites as an important symptom; this symptom is non-specific to hypothermia and is of limited utility for most web page readers.

Prevention guidance reflected widely varied SORT grades; wearing appropriate clothing in layers was the most frequently stated guidance (76%). While there is a scientific basis to this advice, it is difficult to give concrete guidance in this regard because individual variation impacts cold vulnerability. Nearly one-third of the websites stated that consuming caffeine had a negative impact on the cold response, when in fact the diuretic action of this substance has no appreciable impact on the cold response. In some instances, some guidance based on solid science was not emphasized enough on these websites. For instance, staying dry and not over-exerting was listed on 31% of websites. Staying dry prevents evaporative cooling and not over-exerting allows more of the body's energy reserves to be used for the cold response.

CONCLUSION

An internet search was conducted to obtain websites with hypothermia guidance, and then compare them to peer-reviewed literature to determine their scientific validity. A total of 49 websites were analyzed and compared to 58 peer-reviewed articles. While some symptoms were listed on a high percentage of websites, most other guidance was listed on a smaller percentage of websites. Several populations were highly vulnerable to hypothermia, but these groups were not listed on a considerable percentage of websites.

While much of the guidance is based on some research, it was often not easy to determine where a website got its information from. The authors suggest that not only do websites need to list information sources, but guidance associated with low SORT grades need to be eliminated. Additionally, increased mention of vulnerable populations will help users identify people around them who might be potentially at risk. These suggestions should make web-based hypothermia information more scientifically sound.

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