

**EFFECT OF MILD HYPOTHERMIA ON DECISION  
MAKING PROCESSES**

By

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# EFFECTS OF MILD HYPOTHERMIA ON DECISION MAKING PROCESSES

## Abstract

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Effects of cold have been recognized throughout the centuries. Alexander The Great during his campaign into India, is said to have become unconscious from the cold. With record numbers of individuals choosing to recreate in the outdoors, the effects of hypothermia will become an increasing concern for health care professionals. Are we loosing outdoor enthusiasts and winter recreationalists to the effects of profound hypothermia due to poor decisions being made during the stages of mild hypothermia? The purpose of this paper is to explore the effects of mild drops in core temperature (2-3 degrees C or F), on decision making and mental performance.

The effect of mild hypothermia on mental function and decision making processes may predict whether they will be prone to injury or even death. Even mild lowering of core temperatures may be associated with changes in mental performance (Dutka, Smith, Doubt, Weinberg, Flynn, 1991).

Accidental hypothermia is classified as mild, moderate, and severe. Mild hypothermia is present when core temperature is 34 to 35 degrees C (93.2-95 degrees F), moderate hypothermia exists when core temperature is 28 to 33 degrees C (82.4-91.4 degrees F), and severe hypothermia is a core body temperature of less than 28 degrees C (82.4 F), (Varon, Sadovnikoff, Sternbach, 1992). The most common predisposing factor

for hypothermia and cold injury is impairment of cognitive function (Vretenar, Urschel, Parrott, Unruh, 1994). Signs, symptoms, and treatment of mild hypothermia and the direction health care professionals need to take in prevention will be reviewed.

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## Effects of Mild Hypothermia on Decision Making

### Introduction

On March 15, 1997, several buses loaded with school age children headed to the ski area at Mt. Hood, Oregon. The air temperature was 33 degrees F, and raining. Undaunted by the weather conditions, hundreds of children attacked the slopes with skis and snowboards. T.J., a 13 year old boy stayed out in the inclement weather all day long. Slowly his clothing became saturated by rain and his body temperature dropped.

Determined to continue snowboarding despite being totally soaked, he separated from his friends, made a wrong turn and ended up at the bottom of a lift that was closed for the day. He had no way out. Fortunately, a ski area employee saw the boy make the wrong turn and sent the ski patrol to go retrieve him.

Upon arrival at the Mt. Medical Clinic, the boys tympanic temperature was 92 degrees F (33 degrees C). When asked to start taking off his wet clothes, he was unable to negotiate the zipper on his jacket, or even get a tee shirt off over his head, he had difficulty forming sentences and his speech was somewhat garbled. He also had trouble with balance. An outer non-waterproof jacket was removed, plus four layers of cotton shirts. He was externally rewarmed and appeared to be back to normal two hours later.

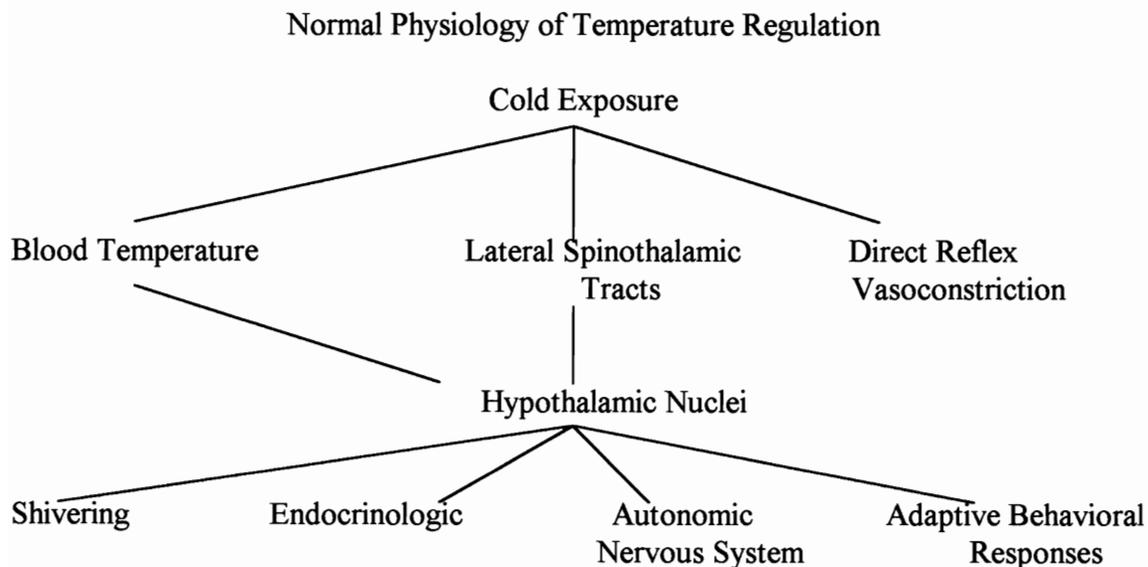
Was the wrong turn he took at the top of the run due to decreased mental performance.?

Hypothermia is the leading cause of death in rescuers and adventures. Core temperatures in humans of less than 35 degrees Celsius (95 degrees F) are defined as hypothermia. The physiological affects of profound hypothermia and its detrimental consequences have been well documented. Treatment modalities and even new criteria for determining death in profoundly hypothermic patients has been established.

But, how do individuals become profoundly hypothermic? Is it due to poor decisions that are being made during the stage of mild hypothermia? Can we educate the public to the signs and symptoms of mild hypothermia so interventions can be made before decision making capabilities are impaired?

### Physiology

Normal thermoregulation involves transmission of cold sensation to hypothalamic neurons via the lateral spinothalamic tracts and the thalamus. Temperature sensitive hypothalamic neurons react directly to alterations in blood temperature and impulses from nerves originating in the skin. The maintenance of homeothermia is affected by both physiological biochemical factors and behavioral responses (MacKenzie, M.A., 1997).



The primary autonomic effector mechanisms include metabolic heat production. With the perception of cold stress, pre-shivering muscle tone is increased. Heat is

generated by involuntary shivering. Stimulated from the posterior hypothalamus and spinal cord, shivering thermogenesis can increase metabolic rate 2 to 5 times until glycogen depletion and exhaustion ensue (Auerbach & Geehr, 1989). Shivering, hyperthyroidism, sympathetic stimulation, and fever can augment thermogenesis by up to 400%, and during exercise, heat production can increase ten fold (Lee-Chiong, T.L., & Stitt, J.T., 1995).

Nonshivering thermogenesis results from metabolic activities. Cold activates the release of thyrotropin-releasing hormone from the hypothalamus. This stimulates the anterior pituitary to produce thyroid-stimulating hormone (TSH), and the thyroid to release thyroxine (Auerbach & Geehr, 1989). Thyroid hormones increase the activity of membrane bound  $\text{Na}^+\text{-K}^+$  ATPase, and increase heat production, and stimulate oxygen consumption (McPhee, S. J., Lingappa, V.R., Ganong, W.F., & Lange J.D., 1995).

Adrenocorticoids, insulin, and catecholamines are also affected by cold stress. Epinephrine and norepinephrine increase the metabolic rate and stimulate the nervous system and heart. Diminished insulin release increases the breakdown and release of stored fuel and allows muscles to utilize glycogen stores for energy (McPhee, S.J., et. al., 1995). Increased cortisol levels stimulate glucagon release which helps supply exercising muscles with glucose and fatty acids by increasing hepatic glucose output and lipolysis of fat stores.

The hypothalamus is very cold sensitive and compensatory responses become depressed in hypothermic states. Humans have to rely on behavioral thermoregulatory measures in order to maintain normothermia and to survive in cold and moderate climates.

Behavioral responses affect the five mechanisms of heat loss, radiation, conduction, convection, evaporation, and respiration. To minimize heat loss, an individual

must alter the amount of exposed body surface area to these five environmental factors. This is done by creating a micro-environment around the body with adequate layers of insulation and wind-water proof clothing (see Table 1).

Radiation accounts for 55-65% of heat loss and is least when the body is curled up and insulated. Conduction and convection contribute to about 15% of heat loss.

Conductive losses may increase five times in wet clothing. Moving air washes away the layer of warm air surrounding the body replacing it with cool air. This convective loss is known as the wind chill effect. The 20-30% heat loss from evaporation and respiration is affected by relative humidity and ambient temperature (Auerbach & Geehr, 1989).

#### Pathophysiology

Hypothermia produces a marked linear decrease in cerebral blood flow, 7% decrease per degree centigrade, (Greeley, Ungerleider, & Kern, 1989). In a study on the effects of cardiopulmonary bypass on cerebral blood flow in neonates, infants and children, and in a comparison study in adult cardiac patients, major external factors were manipulated by an extracorporeal circuit. In evaluating, carbon dioxide, perfusion pressure, pump flow rate, and temperature, temperature was the most important factor influencing cerebral blood perfusion during cardiopulmonary bypass (Greenley, Kern, Meliones, & Ungerleider, 1993). Hypothermia provokes a fall in metabolic rate and cerebral blood flow of about 7% per degree C decrease in core temperature (MacKenzie, Vingerhoets, Colon, Pincker, & Notermans, 1995). The extent to which impaired cerebral function can be attributed exclusively to the reduction in core temperature has yet to be established (see Table 2).

Temperature changes have a major impact on the function of the nervous system by alterations in synaptic gain, synaptic and conduction delays, and amplitudes and durations of action potentials (Markand, Warren, & Mallick, 1990). Temperature changes may also be associated with defects in mental performance, including changes in memory and reaction time. Recordings of evoked potentials and electroencephalograms are the primary neurophysiologic methods for monitoring of the functional integrity of the central nervous system (see Table 3).

### Research Findings

The Naval Medical Research and Development Command studied the P3 electrical response of the brain in divers following extended exposure to water at 5 degree C, and correlated the response to rectal temperatures (Dutka, et al., 1991). The P3 latency has been postulated to be a measure of the speed of processing information in the brain. The P3 electrical response of the brain to unexpected stimuli, and the delay from stimulus to P3 occurrence was measured (P3 latency was related to reaction time). There was a very significant lengthening of the P3 latency related to rectal temperature in the ranges of 35 to 37 degree C, suggesting the possible existence of mental impairment even with minimal bodily cooling. This mild hypothermia may influence the diver's awareness and speed of evaluation of changes in his environment that constitutes a threat to his survival. Since the P3 is a sensitive measure of mental disturbance, it could overestimate the risk of mental impairment. Highly motivated and trained individuals may be able to overcome these mental performance deficits, given appropriate training and experience of the cold environment (Dutka, et. al., 1991).

Simulated conditions of hiking in rain, wind and cold, without protective rainwear, were used to investigate wet-cold hypothermia in 18 male subjects. Thermal metabolic, and motor responses were monitored during an attempted 5 hour walk with continuous exposure to rain and wind over the final four hours. Only 5 of the 18 participants were able to finish the 5 hour hike (Thompson & Hayward, 1996).

The findings of this study confirm that rain and wind present a severe thermal challenge to humans participating in outdoor activities without protective rainwear, even when the temperature is only moderately cold (0-10 degree C). No significant core hypothermia was noted despite the intense, cold discomfort expressed by the subjects and the fact that more than two thirds withdrew from the experiment before completion. The average core temperature was 36.4 degrees C after 5 hours. This temperature attests to the fact that wet-cold discomfort may potentiate behavior that could lead to an increased probability of significant core hypothermia (Thompson, & Hayward, 1996). The severe peripheral cooling was found to impact both motor and psychological performance. Even though individuals were not significantly hypothermic early in the wet-cold exposure, the inability to sustain functional motor skills may be dangerous in a survival situation.

Changes in behavior were also observed. The subjects became withdrawn. They walked with their heads down, eyes groundward, and inattentive to their surroundings. Reduction in cognitive performance could also compromise survival (Thompson, et. al. 1996).

McKenzie, et. al., (1995), studied four women with acquired poikilothermia defined as a variation in core temperature of more than 2 degree C due to changes in ambient temperature. The cause of poikilothermia was probably of hypothalamic origin.

Evoked potentials, auditory, visual and somatosensory, were measured. During mild spontaneous sustained hypothermia, both the latencies of evoked potentials and peripheral nerve conduction velocities were all markedly delayed. These women, due to prolonged mild hypothermia exhibited neuropsychiatric symptoms of progressively impaired mentation, lethargy, bradyphrenia (slowing of mental activity), confusion, disorientation, disorders in short-term memory, stumbling gait, slurred speech, and the occurrence of epileptic seizures. These clinical manifestations correspond to the symptoms experienced by individuals experiencing accidental hypothermia. To improve the quality of life for these women it was of the utmost importance to maintain normothermia (MacKenzie, et. al., 1995). The markedly attenuated neurophysiological and neuropsychological function despite only mild hypothermia underlines the importance to maintain normothermia in outdoor enthusiasts.

Central nervous system cooling probably interferes with mental processing although discomfort and/or the physiological aspects of speech, may also affect performance (Geisbrecht, Arnett, Vela, & Bristow, 1993). To exclude the extraneous variables associated with the discomfort of hypothermia, Giesbrecht, et. al., 1993, administered tests to subjects immersed in cold water that would be minimally or not at all influenced by decreased motor speed, coordination or strength since these factors are known to be affected by hypothermia.

The Auditory Attention Continuous Performance Test, evaluated the subjects sustained vigilance for simple auditory stimuli. The Benton Visual Recognition Test, evaluated complex visual perceptual organization ability and short-term visual memory. The Stroop Word and Color Test, assessed each subjects susceptibility to interference by

competing response tendencies, and the Digit Span Task measured attention concentration, vigilance for auditory stimuli and short-term memory.

Results indicated that tests requiring little cognitive demand, such as auditory attention, visual recognition and forward digit span, were not affected by cold water immersion with core cooling. More complex tests and analysis, showed a slight improvement upon cold water immersion (probably due to arousal of learning) but a subsequent decrease when core cooling of 2 to 4 degrees C occurred (Hayward, & Keatinge, 1979).

Collins, Abdel-Rahman, Goodwin, and McRiffin (1995) studied Circadian Body Temperatures and the effects of cold stress in the elderly and young adults. After six hours in cold conditions, core urine temperature fell by only 0.4 degrees C and both groups reported an increase in arousal to learning.

## Discussion

Several conclusions can be drawn from the studies reviewed. Even with excluding the extraneous variable of physical discomfort associated with hypothermia, cognitive function was affected by mild drops in core temperature. This alteration in cognitive function was exhibited even before the subjects core temperature reached the clinical definition of mild hypothermia. The delay in responses and judgment can put an individual at risk for injury or continuance into more profound hypothermic states.

The women who were poikilothermic, exhibited all the symptoms associated with hypothermia due to environmental exposure. Impaired mentation, lethargy, bradyphrenia, confusion, disorientation, stumbling gait, slurred speech were all symptoms observed in the 13 year old snowboarder brought to the Mt. Clinic.

Most importantly, these studies show there is an early period of time during the mild hypothermic state where there is a heightened state of arousal. If people are educated to the signs and symptoms of hypothermia and can be taught what life saving measures should be taken, they may be able to prevent further injury or even death.

Health care practitioners are frequently in a position to help educate the public concerning health maintenance issues. Prevention is always better than a cure and educating the public on how to avoid hypothermia is essential. Prevention must focus on education, preparation (rest, nutrition, hydration), and insulation from the cold. People must be educated in how to create their own micro-environment, in order to maintain normothermia in cold climates. They must also have an understanding of the principles of heat conservation and loss. To be prepared physically and mentally for the challenges of the wilderness setting.

Dressing in layers that consist of hydrophobic materials, and an outer layer that is wind and water proof, allow people to adjust clothing to minimize heat loss from conduction, convection, evaporation, radiation, and respiration. Cotton (the death cloth), should be avoided in any cold, wet environment. Once it is wet it stays wet and pulls heat away from the body (Ha, Tokura, Tanake, & Holmer, 1996). The uncovered head can lose a large percentage of the body's total heat production. Hats should be made of wool or one of the new high tech materials. Water proof gloves and wool or synthetic socks should also be worn. Once garments become wet, they must be changed promptly.

Good physical conditioning with adequate rest and nutrition are an absolute prerequisite for anyone planning a outdoor adventure. Dehydration must be avoided.

Drinking from a cold stream is preferable to snow ingestion, since it requires significant energy to convert ice at 0 degrees C to water at 0 degrees C.

The buddy system is best and each person should watch the other for hypothermic signs. Wet clothing, uncomfortable cold feeling, and shivering are signs that should be heeded. At these signs, individuals should remove themselves from the cold environment, seek shelter, and change wet clothing.

Always make sure someone at home knows your game plan. If for some reason you spend an unexpected night out, it makes it easier for search and rescue personnel to find you if they know where you were headed.

With thousands of individuals choosing to recreate in the outdoors, health professionals will be seeing people who are affected by hypothermia. The symptoms could range from mild to profound. But, in most instances hypothermia can be avoided through simple preventative measures. Health education on appropriate attire for outdoor adventures can help preserve the cognitive function needed in a wilderness environment, and prevent a disastrous outing.

Table 1

## Creating a Micro-environment

1. Apply a layer of thermal underwear. This should be of a synthetic material such as polypropylene, capalene, or thermax.
2. Add midlayers. This can consist of heavier weight polypropylene or capalene, a wool sweater, a fleece pullover, or a down vest.
3. Top with waterproof, windproof outerwear.
4. A scarf or neck gaiter over the nose and mouth helps pre-warm inhaled air.
5. Don't forget to accessorize with a wool or synthetic hat, insulated waterproof gloves, and synthetic socks.

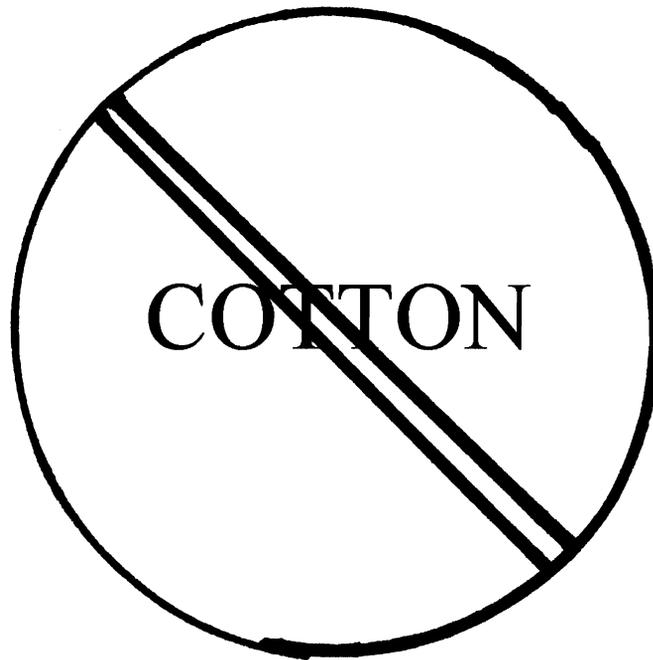


Table 2

## Characteristics of the Three Hypothermia Zones

<b>Zone</b>	<b>Temperature</b>		<b>Characteristic</b>
Mild	37.6 C	99.6 F	Normal rectal temperature
	36 C	96.8 F	Increase in metabolic rate
	35 C	95 F	Maximum shivering thermogenesis
	34 C	93.2 F	Amnesia, poor judgment develops, maximum respiratory stimulation
	33 C	91.4 F	Ataxia and apathy develop
Moderate	32 C	89.6 F	Stupor, decreased oxygen consumption
	31 C	87.8 F	Extinguished shivering thermogenesis
	30 C	86 F	Arrhythmias develop; cardiac output two-thirds of normal; insulin ineffective
	29 C	85.2 F	Continued decrease in LOC, pulse, and respiration
	27 C	80.6 F	Loss of reflexes and voluntary motion
Severe	26 C	78.8 F	Acid-base disturbances; no reflexes or response to pain
	25 C	77 F	Cerebral blood flow one-third of normal; cardiac output 45% of normal
	23 C	73.4 F	No corneal or oculocephalic reflexes
	22 C	71.6 F	Maximum risk of ventricular fibrillation
	19 C	66.2 F	Flat EEG
	18 C	64.4 F	Asystole

Table 3

## Pathophysiological Consequences of Hypothermia

## General

- Shivering, hypermetabolism, and peripheral vasoconstriction during mild hypothermia
- Decline in metabolic rate during profound hypothermia.

## Cardiac

- Myocardial depression moderate hypothermia
- Arrhythmias, progressive heart block, and asystole in severe hypothermia.

## Metabolic

- Reduction in oxygen consumption with moderate hypothermia.
- Impaired drug metabolism and clearance.

## Renal

- Cold diuresis in mild hypothermia.
- Depressed tubular enzymatic activity.
- Reduced renal blood flow

## Pulmonary

- Central and reflex respiratory depression.
- Increased dead space.
- Edema of bronchiolar epithelium and alveoli
- Decreased mucociliary activity.
- Profuse bronchorrhea.

## Gastrointestinal

- Erosion and ulcerations of stomach and duodenum
- Diminished intestinal motility
- Hepatic dysfunction

#### Endocrine

- Diminished insulin release, increased peripheral insulin resistance.
- Augmented catecholamine release.
- Elevated plasma cortisol

#### Hematological

- Hemoconcentration
- Erythroid maturation granulocytes
- Thrombocytopenia
- Impaired coagulation

#### Neurological

- Decreased cerebral metabolism
- Progressive electroencephalographic changes
- Alterations in visual evoked potentials and peripheral nerve conduction velocity.

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