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# Cold exposure and thermal comfort among patients in prehospital emergency care -innovation research in nursing

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*To Frank, Nea and Runa with love*

*"Vita non est vivere sed valere vita est"*



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# Abstract

**Background** Patients' cold exposure is a neglected problem in prehospital emergency care. Cold stress increases pain and anxiety and contributes to fear and an overall sense of dissatisfaction. When left untreated, cold stress disturbs vital body functions until ultimately reaches hypothermia. Patients, irrespective of diseases or trauma, might experience thermal discomfort because of a cold environment. One of the leading influences of the overall sensation of cold discomfort is cooling of the back. There is a lack of research regarding patients' experiences of cold exposure and thermal comfort in prehospital emergency care. Further, research is lacking regarding the supply of active heat from underneath the body during transport.

**Aim** The overall aim was to investigate patients' experiences of thermal comfort and reactions to cold exposure in prehospital emergency care and to evaluate the effects of an intervention using active warming from underneath. The specific aims were; to explore patients' experiences of being cold when injured in a cold environment (**I**), to investigate injured and ill patients' experiences of cold exposure and to identify related factors during ambulance care (**II**), to evaluate the effect of a heated ambulance mattress-prototype on body temperatures and thermal comfort in an experimental study (**III**), and to evaluate the effect of a an electrically heated ambulance mattress-prototype on thermal comfort and patients' temperatures in the prehospital emergency care (**IV**).

**Method** Study **I**: Persons (n=20) injured in a cold environment in the north of Sweden were interviewed. Active heat was given to 13 of them. The interview data was analysed with qualitative content analysis. Study **II**: In wintertime, 62 patients were observed during prehospital emergency care. The field study was based on observations, questions about thermal discomfort, vital signs, and temperature measurements. Study **III**: Healthy young persons (n=23) participated in two trials each. Data were collected inside and outside a cold chamber. In one trial, the participants were lying on a regular ambulance stretcher and in a second trial on a stretcher supplied with a heated mattress. Outcomes were the Cold Discomfort Scale (CDS), back, finger, and core body temperature, four statements from the State-Trait-Anxiety-Inventory (STAI), vital signs, and short notes about their experiences of the two stretchers. Study **IV**: An intervention study was conducted in prehospital emergency care in the north of Sweden. The patients (n=30) in the intervention group were cared for in an ambulance supplemented with a heated mattress on the stretcher, whereas only a regular stretcher was used in the ambulance for the patients (n=30) in the

control group. Outcomes were the CDS, finger, core body, and air temperature, and questions about cold experiences.

**Results** Study I: It was devastating to lie on the cold ground. Patients suffered more because of the cold than from the pain of their injuries. The patients were in a desperate need of heat. Patients who received active heat experienced it in a positive way as it relieved suffering. Study II: Patients are exposed to cold stress due to cold environments. There was a significant decrease from the first measurement in finger temperature of patients who were indoors when the ambulance arrived, compared to the measurement taken in the ambulance. In the patient compartment of the ambulance, 85% of the patients had a finger temperature below the comfort zone and almost half of them experienced the patient compartment in the ambulance to be cold. The regular mattress surface temperature at the ambulance ranged from -22.3 to 8.4 °C because of the mattress quickly adapting to the surrounding air temperature. Study III: A statistical increase of the participants' back temperature was found between those lying on the heated mattress compared to those lying on the regular mattress. When lying on the heated mattress the statement "I'm tense" was lower rated, whereas the statement "I feel comfortable", "I'm relaxed", and "I feel content" were higher rated, compared to when lying on the regular mattress. The heated mattress was experienced as warm, comfortable, providing security, and easy to relax on. Study IV: Thermal comfort increased for the patients in the intervention group and decreased in the control group. A significant higher proportion of the participants rated the stretcher as cold to lie on in the control group (57%) compared to the intervention group (3%).

**Conclusion** The ambulance milieu is too cold to provide thermal comfort, and the patients react immediately to cold exposure with discomfort and decreasing finger temperatures. There is a potential for improvement using active heat supply in prehospital emergency care. Heat supply from underneath increased comfort and might prevent cold stress and hypothermia. It is an important nursing intervention recommended for injured and sick patients in prehospital care.

**Keywords** Thermal comfort, thermal discomfort, cold exposure, cold stress, hypothermia, patients' experiences, active warming, prehospital emergency care, finger temperature, back temperature.

## Original papers

The original papers are referred to in the following text by their Roman numerals.

I Aléx J., Lundgren P., Henriksson O., Saveman B-I. Being cold when injured in a cold environment – Patients’ experiences. *International Emergency Nursing* 2013, 21, 42–49.

II Aléx J, Karlsson S, Saveman B-I. Patients’ experiences of cold exposure during ambulance care. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* 2013, 21(1):44.

III Aléx J, Karlsson S, Saveman B-I. Effect evaluation of a heated ambulance mattress-prototype on body temperatures and thermal comfort- an experimental study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* 2014, 22:44.

IV Aléx J, Karlsson S, Björnstig U, Saveman B-I. Effect evaluation of a heated ambulance mattress-prototype on thermal comfort and patients’ temperatures in prehospital emergency care - an intervention study. Submitted to *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*

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# Abbreviations

BP	Blood Pressure
BMI	Body Mass Index
°C	Degrees Celsius
CDS	Cold Discomfort Scale
Clo	Clothing and thermal insulation value
ED	Emergency Department
ECG	Electrocardiograph
SD	Standard Deviation
E	Effect size
HR	Heart Rate
Sat	Oxygen saturation
Ta	Air temperature
Tf	Finger temperature
Tcb	Core body temperature (internal ear)

## Concepts used in thesis

Cold exposure is a persons' subjective experience of the environment being too cold to experience thermal comfort.

Thermal comfort is a state in which there is no driving impulses to correct the environment by the behaviour (Hensen, 1991).

Cold stress is a state of physical and psychological responses to untreated cold exposure.

Hypothermia is a core body temperature  $\leq 36$  °C (Burger and Fitzpatrick, 2009).

Comfort is the experience of receiving effective care that meets comfort needs (Kolcaba and Fisher, 1996).

Nursing research is used interchangeable to health care research and caring research.

Nurse includes specialized prehospital emergency nurses, registered nurses, and nurse assistants.

# Abstrakt på svenska

**Bakgrund** Det är vanligt att sjuka och skadade patienter i ambulanssjukvården under vintertid exponeras för ett kallt klimat. Detta är ett problem som är eftersatt och inte åtgärdat. Att bli kall kan leda till obehagskänslor och vidare till svikt av vitala funktioner, om inte avkylningen stoppas. Att bli kall på ryggen har visat sig vara vanligt relaterat till den övergripande känslan av obehag av kyla. Forskning om patienters upplevelser av kyla-exponering och termisk komfort i ambulanssjukvården fattas. Vad jag har sett finns det ingen forskning om aktiv värme underifrån till patienter under ambulanstransport.

**Syfte** Det övergripande syftet var att utforska patienters upplevelser av termisk komfort och deras reaktioner vid kyla-exponering. Specifikt avsågs att undersöka upplevelser av att bli kall hos patienter som skadat sig utomhus i kallt klimat (**I**). Vidare avsågs att undersöka sjuka och skadade patienters upplevelser av kyla-exponering och relaterade faktorer i ambulanssjukvården (**II**). Ett experiment utfördes med en värmemadrass på unga, friska deltagare, i avseende att utvärdera temperaturer och upplevelser av termisk komfort (**III**). Slutligen avsågs att testa värmemadrassen på patienter i ambulanssjukvården i avseende att utvärdera effekten av termisk komfort och patienters temperaturer (**IV**).

**Metod** För att undersöka patienternas upplevelser av att skadas i kallt klimat i norra Sverige genomfördes intervjuer. Av de 20 inkluderade patienterna hade 13 fått aktiv värme i form av kemiska värmepplattor på bröstkorgen (**I**). Under ambulanssjukvårdens omhändertagande av 62 patienter ställdes frågor om termiskt obehag och vitala parametrar och temperaturer registrerades (**II**). I experimentstudien medverkade 23 friska, unga personer i två försök var. Data samlades in i och utanför en köldkammare. I ena försöket fick de ligga på en vanlig bår och i det andra försöket på en bår med tillägg av en elektrisk värmemadrass. Mätningar gjordes av termiskt obehag (Cold Discomfort Scale, CDS), rygg-, finger-, och kroppstemperaturer. Ytterligare användes fyra antaganden från ett instrument, State-Trait-Anxiety-Inventory (STAI), som i sin helhet mäter aktuell psykisk belastning. Vitalparametrar mättes och korta kommentarer från deltagarna angående de båda försöken insamlades (**III**). Interventionsstudien genomfördes i ambulanssjukvården på patienter i norra Sverige. I interventionsgruppen ingick 30 patienter som transporterades på en bår med tillägg av en elektrisk värmemadrass. I kontrollgruppen ingick 30 patienter som låg på en vanlig ambulansbår. CDS,

finger-, kropps-, och lufttemperaturer i ambulanshytten mättes samt att frågor om kyla ställdes och noterades (IV).

**Resultat** Det var förödande för patienterna att bli liggande på den kalla marken. De upplevde snabbt att kylan underifrån spred sig i kroppen de blev genomkalla och det upplevdes som mer allvarligt än själva skadan. De var i kraftigt behov av värme och det uttrycktes att ambulanshytten var för kall. De som fick aktiv värme upplevde det positivt och det minskade lidandet (I). Patienterna exponerades för kalla temperaturer från att ambulansen anlät till ankomst på akutmottagningen och de reagerade på köldstressen med sänkta fingertemperaturer. Cirka 85% hade en fingertemperatur under komfort zonen. Nära hälften av patienterna upplevde att ambulanshytten var kall. Madrasstemperaturen visade mellan -22.3 °C och +8.4 °C innan lastning på grund av materialets snabba adaptation till omgivningstemperaturen (II). Försöket med värmdmadrassen visade en statistisk ökning av ryggtemperaturen jämfört med försöket när de låg på en vanlig madrass. Vidare skattades "Jag är spänd" lägre och "Jag har det skönt", "Jag känner mig avspänd" och "Jag känner mig nöjd" högre när deltagarna låg på den varma madrassen jämfört med när de låg på den vanliga bären utan värmemadrassen. Värmemadrassen upplevdes som varm, behaglig och den förmedlade en känsla av säkerhet och var lätt att slappna av på (III). Den termiska komforten ökade för patienterna som låg på värmemadrassen och för patienterna som låg på den vanliga madrassen minskade den termiska komforten under omhändertagandet. En större proportion av patienterna skattade att bären var kall att lägga sig på i kontrollgruppen (57%) jämfört med patienterna i interventionsgruppen (3%), som låg på värmemadrassen.

**Slutsatser** Det är kallt för patienter i ambulanssjukvården vintertid och ambulansmiljön är för kall för att erbjuda termisk komfort. De reagerade direkt på kyla-exponeringen med sänkt fingertemperatur. Det finns potential att förbättra den termiska komforten för patienterna i ambulanssjukvården. Värmetillförsel med en elektrisk värmemadrass ökar komforten och motverkar de negativa konsekvenserna från köldstress. Värmemadrassen bidrar till en bättre vård i en kall miljö och rekommenderas för användning i ambulanssjukvården.

# Introduction

Historically, the knowledge of fire control, the first active heat source, has been important for the human evolution. Fire has always been essential to humans and has contributed to protection, light, cooking, and tool making. Active heat has also contributed to obtaining warmth and a sense of comfort to our ancestors (Wrangham, 2009). Cold exposure is a constant threat to human health and has always been so. It is evident that circumpolar inhabitants are exposed to cold in significant portions of their everyday life. In Sweden, located between latitude 55°-69°, the number of days per year when the daily mean temperature is below 0 °C is between 73 in the south to 219 days in the north, (mean days 143/ year; 2.4-7 months) (Statistics Sweden, 2013).

Cold exposure in wintertime may be common, followed by cold stress if the person is not protected or isolated from the cold. Sick and injured persons are especially sensitive to cold exposure and are particularly vulnerable. To care for injured or acutely ill patients is to protect their lives, health and dignity and from complications. Caring is also the promotion of healing and safety, decreasing suffering, and releasing patients' burdens (Kolcaba, 1991). To fulfil these nursing goals, it is, important to assess the ill and injured patients' objective signs and their experience of cold exposure especially in wintertime.

Having worked many years as a specialized prehospital emergency care nurse, my pre-understanding is that ill and injured patients in prehospital emergency care often complain of cold exposure and their thermal comfort needs are not always met with, for example, active warming. Further, from my observations, the care for patients who experience cold stress is mostly based on local traditions and not on research.

Nursing research can be divided into two trends. One is the focus on developing concepts and knowledge about basic phenomenon in health care. The second strives to develop knowledge by evaluating and improving new methods in clinical practice (Wiklund, 2003). By focusing on cold exposure among patients in prehospital emergency care, this thesis is based on improving methods for clinical use and focusing on aspects such as the environment, conservation of energy, and comfort. To use both a nursing and a medical perspective gives a broad understanding of patients' experiences and reactions to cold stress and thermal comfort. Enhanced knowledge of how to improve thermal comfort for patients in prehospital emergency care research in clinical practice may be useful.

# Background

Nursing interventions are needed when the patient cannot respond adequately to maintain a stable environment (Levine, 1967). Several theories in nursing discuss the necessity of warmth and comfort to support the body's healing power (e.g. Nightingale, 1863, Henderson and Silfvenius, 1982). When people are injured or become ill the possibility to satisfy their thermal needs on their own declines or vanishes, and they become more dependent on the nursing care. Physiological needs, like heat, are one of the most fundamental human needs (Maslow, 1943), and are seen as having to be fulfilled before it is possible for one to feel safe (Maslow et al., 1970). In the present thesis, Levine's Conservation Model (Levine, 1967) and Kolcaba's Theory of Comfort (Kolcaba, 1991) were chosen as theoretical frames which can be applied and discussed toward the topics of the thesis.

## **The conservation of energy**

Levine states that human life requires and produces energy and that the conservation of this energy is vital in nursing care and provides the basis for a comprehensive and holistic nursing practice (Levine, 1967). Levine's four principles of conservation are based on nursing actions to preserve or recover the person's health. The central concept of Levine's theory is conservation. Levine's model guides nurses in the provision of care that will help support the patients' health (Levine, 1967). When a person is in a state of conservation, it means that there has been an effective adaptation to the health challenges with the least amount of effort. The main focus in Levine's Conservation Model is to promote the physical and emotional wellbeing of a patient by addressing the four areas of conservation.

1. The conservation of energy, that is, making sure the patient has the required energy for healing functions.
2. The conservation of structural integrity is a result of adaptation to internal aspects (physical aspects, e.g., cells, tissues and fluids that provide function) and external environments (performing activities or tasks that help the patients' physical healing).
3. The conservation of personal integrity is used when helping patients maintaining individuality such as giving a choice in how care is administered.
4. Finally, the conservation of social integrity, is assisting the patient in maintaining social and community links; increasing their support system to help the client's sense of self-worth (Levine, 1967).

## Comfort and thermal comfort

Historically, comfort is identified as a basic element in nursing care (Paterson and Zderad, 1988, McIlveen and Morse, 1995, Kolcaba and Kolcaba, 1991). Kolcaba's theory of comfort specifically addresses the practice concept of nurse-provided comfort (Kolcaba, 1991). Human beings have need for comfort and will seek comfort whenever possible. Nursing care can assist and provide comfort to patients who are enduring and suffering from illness or injuries (Morse, 1997, Kolcaba, 1991). Kolcaba states three types of comfort.

1. Relief is when a patient's specific need is seen and cared for.
2. Ease is a patient experience of calm and contentment.
3. Transcendence is when a patient rises above problems and pain (Kolcaba and Fisher, 1996).

Discomfort, at the other end of the comfort continuum, is seen as a lack of wellbeing, ease, or relief from suffering (Allen, 1990, Paterson and Zderad, 1988, Eriksson, 1994). Eriksson (1994), describes that patients are more or less exposed, and vulnerable related to their need for care. She stresses that when the caregiver cannot offer a good caring that strengthens the wellbeing process, suffering from care can emerge, for example, suffering due to non-caring, maltreatment, wrong medical treatment, or impaired care of cold exposure. The experience of comfort occurs within different contexts such as physical influence to bodily sensations and environmental sensitivity to external surroundings (Kolcaba and Fisher, 1996).

Thermal comfort is a result of preventive treatment of cold stress and hypothermia. A person's sense of thermal comfort is primarily a result of the body's heat exchange with the environment. The experience of thermal comfort differs among ill and injured people compared to healthy people because the physical disability can affect the thermo-physiology such as, thermal sensation, blood flow, metabolism, regulatory response as vasomotor control of body skin temperature, and the ability to sweat. Humans can only be in the thermal comfort zone when heat production and heat loss are in balance (Kingma et al., 2012). In a thermally comfortable environment, no cold or heat should be experienced (Fanger, 1973). Consequently cold environments are a challenge to the human heat balance and protection.

## **The environment in prehospital emergency care**

The environment in prehospital emergency care can vary a lot, starting from, for example, in a patient's own home, at a traffic crash, or at a disaster situation. Furthermore, all environments can vary in ambient temperatures depending on the time of the year. Cold environments represent a challenge to the human heat balance and require several caring methods to guarantee thermal comfort (Holmér, 2004). The milieus and ambient temperatures can contribute to the complexity of providing prehospital emergency nursing. Additionally, all patients are exposed to being outside for a short period, even those who are indoors at arrival to the patient.

There has been a fast technical evolution since the 1990's (Barnard and Sinclair, 2006) and, in general, the patient care has been increasingly focused on monitoring apparatuses and surveillance technology (Lyon, 2003). Technical equipment can, however, lead to nurses becoming preoccupied with measurements and medical equipment and thereby not pay adequate attention to the patient cared for. One example is that the status of organs and their function rule nurses' actions leading to patients that might not feel seen (Almerud et al., 2008).

In nursing, people are seen as responding holistically to complex stimuli, for example, cold exposure that produces discomfort and can trigger anxiety (Kolcaba and Wilson, 2002). Addressing psychological needs is a valuable contribution to holistic care (Wagner et al., 2006). One fundamental concern in nursing is to keep the patient stable by evaluating the influences and effects of environmental stressors to obtain the highest degree of wellness possible at the time (Neuman and Fawcett, 1989). However, nursing need a caring approach which also include to be aware of and ask for patients own experiences and for nurses to have competence enough to make own professional assessments irrespective of how critically ill the patient is (Wireklint Sundström and Dahlberg, 2011).

## **Vulnerable patients in prehospital emergency care**

In prehospital emergency care, it is important to recognize patients predisposed to cold exposure. Three groups of predisposed patients are common in pre-hospital care and need to be recognized; (i) those with reduced heat production (ii) those with extra heat loss (iii) and those with impaired thermoregulation. First, (i), infants have excessive heat loss related to difficulties in increasing their heat production, and they have a large surface area in relation to body mass. Old people often show diminished autonomic function (Collins et al., 1980), reduced skin blood flow (Wagner

and Horvath, 1985) and impaired thermoregulation (Marion et al., 1991) because of reduced muscular mass, impaired neuromuscular coordination and decreased heat production. Second, (ii) pharmaceutical medications such as opioids, benzodiazepines, phenothiazine, and barbiturates are predisposing factors which may suppress thermogenesis and thermoregulation. Alcohol dilates the vessels of the skin increasing heat loss (Corneli, 2012). Third, (iii) injuries to the central nervous system (CNS) and traumatic brain injuries can affect the thermoregulatory centre in the hypothalamus and mediate vasodilation, leading to heat loss. A lesion of the spinal cord eliminates peripheral thermoregulation distally to the injury. Injuries to the skin and muscles influence the reflex path of the peripheral thermoreceptors and nerves (Keim et al., 2002). Further, metabolic disorders such as diabetes impair thermoregulation (Danzl and Pozos, 1994).

In general, patients in prehospital emergency care are already suffering for other reasons than of cold. These examples of aspects mentioned above are common among patients in prehospital emergency care and make them vulnerable. It is important to strive to get a holistic view of the prehospital emergency patient to understand all relevant aspects. A body complaint will affect not only the body, but also the whole human (Kallenberg and Larsson, 2000). To get a broader understanding of the patients' experiences of and responses to thermal comfort, knowledge about human thermoregulation, heat transfer, cold exposure, cold stress, and hypothermia is needed.

## **Human thermoregulation and heat transfer**

The basal metabolic energy is the energy needed to drive the body's chemical reactions and produce heat to maintain a body core temperature of 37 °C (Auliciems et al., 1997). A 20 °C ambient temperature requires the metabolic energy production to double to maintain the body core temperature. Peripheral cooling of blood activates peripheral vasoconstriction and an increased metabolic rate, shivering thermogenesis. The body's thermoregulatory mechanisms do their best to balance heat production against heat loss. Heat conservation mechanisms, however, are not as well developed as heat shedding mechanisms. Humans may work well in warm climates, but cold climates need different adaptations to conserve body heat (The National Board of Health and Welfare, 2002).

Heat transfer is known as transfer of heat to cold environments (Pellerin et al., 2004). Most of the energy produced within the human body is given off into the environment via the body surface. When the body is in the temperature comfort zone, skin temperature varies from 31 – 34 °C (Auliciems et al., 1997). The skin temperature is lower than the core body

temperature and is affected by the ambient temperature (van Marken Lichtenbelt et al., 2002). The thermoregulation system is relatively powerful compared to other systems, for example, the body attempts to maintain the core body temperature even during starvation (Hensel, 1981).

Laws of physics affect the human body. The first law of thermodynamics states that energy is neither created nor destroyed but can be transformed from one form to another. The second is that heat flows spontaneously from a hot to a cold body, but never the reverse. Four mechanisms allow heat to be lost from the skin: Conduction; heat loss from a warm object or body when it comes in contact with a colder object, for example, a warm body on a cold floor. Convection; heat lost directly into the air. The faster the wind blows, the more heat is lost. That means that a warm body heats the air surrounding it, but when warm air is replaced by cold air blowing across it, heat is lost. This is the case for a person not insulated from wind and cold air. Radiation; heat constantly emitted by a warm object. On a cold day, the radiation losses may be pronounced from unprotected skin areas. Evaporation; liquid changes into vapour, a process that requires energy to convert liquid to a gas. This is an important cooling mechanism, for example, a wet patient (Tsuei and Kearney, 2004, Giesbrecht and Wilkerson, 2006, Keim et al., 2002).

In prehospital care the following risk factors for decreased thermal comfort may be worth considering in cold environments: Conductively heat flows into the ground from an uninsulated patient and radiation heat disappears from an uncovered head. A breeze rips heat away via convection. Evaporation on a wet patient further decreases temperature. Each of these factors may lead to a drop in core temperature, and in situations where several risk factors are present the affects may be compounded.

### **Cold exposure, cold stress, and hypothermia**

If the cold exposure is greater than the defence from it, such as taking shelter or increasing metabolic heat, cold stress occurs. Cold stress generally produces discomfort before it affects health. Being cold is an uncomfortable, subjective experience (Lintu et al., 2006). In the literature, the terms cold stress and hypothermia are used in various ways (Hooper et al., 2010, Giesbrecht, 2000). Severe untreated hypothermia causes asystole at a body temperature of 18 °C (Danzl and Pozos, 1994). Death from hypothermia is generally from cardiorespiratory failure (Giesbrecht, 2001). The risk of death from severe hypothermia is particularly high in situations of prolonged cold exposure (Palmiere et al., 2014). Cold exposure leading to accidental hypothermia is not limited to a special season of the year (Helm et al., 1995,

Lim and Dufloy, 2008). Studies have shown that patients in subtropical climates are also at risk of developing hypothermia (Helm et al., 1995, Aitken et al., 2009). Cassar and Camilleri (2014) have shown that southern Europe also has its share of hypothermia patients during wintertime.

Direct contact between skin or tissues to colder objects results in heat transfer through conduction (Morrison, 1988). The onset of pain is set at 15°C, numbness at 7 °C and frostbite risk at 0 °C (Geng et al., 2006). Studies have shown that cold finger temperatures increase pain and a sense of discomfort (Schlader et al., 2010). Wang et al. (2007) mean that the finger temperature is probably the body's most sensitive indicator of the thermal state. A change in skin temperature such as from cold exposure (Schlader et al., 2010) results in the primary thermal input directing vasoconstriction responses leading to peripheral blood being shunted to central body regions in order to support vital organs and to retain body heat (Stocks et al., 2004, Lintu et al., 2006, Kurz et al., 1995, Candas and Dufour, 2007, Schlader et al., 2009, Holmér et al., 2012). This leads to an increase in the volume of blood in the central large vessels, which in turn leads to increased diuresis, "cold-diuresis". The cold-diuresis begins within 10 to 20 minutes after cold exposure and can be so intense as to cause involuntary micturition (The National Board of Health and Welfare, 2002).

Cold exposure initiates and increase skeletal muscle tonus, leading to shivering, which can effectively increase heat generation up to four times (Farley and McLafferty, 2008) and vigorous shivering increases metabolic heat production up to six times above basal level (Giesbrecht et al., 1994). While shivering increases heat production, it is also a cause of major discomfort to patients (Vogelsang, 1994).

A meta-analysis showed a clinical significant coagulopathy and an increased blood loss that appears at <1 °C drop in core body temperature (Rajagopalan et al., 2008), which does not reduce haemorrhaging in a normal way (Watts et al., 1999). The decreased core body temperature reduces the function of the coagulation factors and reduces the overall platelet amount through marrow suppression and accumulation of platelets in the liver, portal venous system and spleen (Frank, 2000, Petrone et al., 2003, Doufas, 2003, Tsuei and Kearney, 2004, Valeri et al., 1995). Hypothermia triggers the sympathetic nervous system and the peripheral vasoconstriction leading to hypertension, tachycardia, increased cardiac output, and increased oxygen consumption (Peng and Bongard, 1999).

The immune system might be weakened by impaired leukocytes mobility and phagocytosis due to hypothermia (Sessler, 1997, Kurz et al., 1996, Danzl and Pozos, 1994).

## **Treatment of cold stress**

Achieving thermal comfort is the goal of treating cold stress. Untreated cold exposure can be detrimental in many ways when leading to different levels of cold stress and hypothermia. Adaption to cold exposure needs different actions to conserve body heat. The treatment distinguishes between passive and active warming.

Passive warming is achieved by simple endogenous heat production by the patient without supply of external heat (Keim et al., 2002). Passive warming involves isolation of the patient from the cold with for example blankets (Henriksson et al., 2012, Langhelle et al., 2012), vapour barrier (Henriksson et al., 2012) and bubble wraps (Thomassen et al., 2011). An experimental study on synthetic blankets used in ambulance care shows that they are of little value especially in windy conditions. At 8m/s the insulation was down to about 35% of its original insulation capacity (Henriksson et al., 2009).

Active warming involves the supply of an external heat source such as chemical heating pads, pre-warmed blankets, warm air blankets, and electric blankets (Keim et al., 2002). Most research concerning active heat supply is conducted in hospital settings with heat supply delivered from on top of the participants, such as hot air blankets (Pu et al., 2014). Preoperative active warming, not only prevents hypothermia, but also decreases the incidence of postoperative complications such as prolonged recovery, increased blood loss, arrhythmias or cardiac arrest, impaired immunity, delayed wound healing, and wound infection (Melling et al., 2001, Sessler, 2001).

There are a number of in-hospital intervention studies comparing passive and active warming (Wong et al., 2007, Wagner et al., 2006, Kober et al., 2003, Pu et al., 2014). Wong et al. (2007) showed in an intervention study that two hours of preoperative warming on a heated mattress, compared to standard warming with a forced air warming device (Bair Hugger), reduced blood loss, surgical-site infections, and overall complications. Another study with 126 patients, which started in a prehospital setting, showed that active warming blankets had a positive effect on patients' thermal comfort and they experienced a reduction in preoperative anxiety compared to non-warmed cotton blankets (Wagner et al., 2006). For 90 patients divided into two groups, active warming of the abdomen and lower back region showed decreased pain, anxiety, and nausea score compared to non-warmed patients

(Kober et al., 2003). Finally a study on 110 patients divided into two groups undergoing laparoscopic surgery for gastrointestinal cancer, an underbody forced air warming blanket (Bair Hugger) maintained the patients' core body temperature at a normothermic state compared to those treated with a quilt (Pu et al., 2014).

Lundgren et al. (2009) showed, in their experimental study, that active warming such as chemical active heating pads and hot water bags significantly increased the rewarming rate compared with spontaneous warming. Similar result is seen in the experimental study by Hultzer et al. (2005) when six subjects were cooled on six different occasions each to a core body temperature of 35 °C. Another experimental study on 150 participants showed a larger increase of thermal comfort when using forced-air blankets compared to warm blankets (Leeth et al., 2010).

There are few studies of active warming performed in a prehospital emergency care context. In a clinical randomized trial in prehospital emergency care on 48 patients divided into two groups, cold discomfort decreased when receiving active chemical heat pads on top of the torso compared to patients receiving passive warming only. There was also a decrease in heart rate and respiratory frequency in the intervention group (Lundgren et al., 2011). Ninety patients suffering from acute pain included in another prehospital emergency study, showed that active warming with a carbon-fibre electric heating blanket (n= 47) reduced acute low back pain compared to those who were given a woollen blanket (n=43), ( $p < 0.01$ ). (Nuhr et al., 2004). Patients treated with active warming blankets had higher core body temperature and improved pulse-oximeter monitoring quality compared to patients covered with normal wool blankets (Kober et al., 2002). Active warming blankets used during transport increases patients thermal comfort and core body temperature, reduces pain and anxiety, and improves overall patient satisfaction (Kober et al., 2001). However, there is a lack of research on active heating from underneath in prehospital emergency care.

# Rationale

Treatment with active warming is more effective than passive warming and should, therefore, be used in the prehospital emergency care (Greif et al., 2000) to maintain the patients in a normothermic state. It seems very important to prevent cold stress and hypothermia, which has a severe impact on the whole body system. Nevertheless, despite the knowledge of cold stress, pathophysiology, the advantages of supplying active heat, and that the patients are most exposed to cold furthest out in the caring chain, there is still a lack of active warming in prehospital emergency care. The most common equipment used to prevent and treat cold stress and hypothermia in prehospital emergency care are duvets, plastic “bubble wrap”, and cotton blankets (Karlsen et al., 2013). The fact that all patients in prehospital emergency care lie down on a cold stretcher and that conduction is the most effective way for heat transfer, active warming from underneath may be beneficial for those patients. There is limited knowledge about the ambient temperature the patients are exposed to, and there is a lack of functional methods for preventing cold stress in prehospital emergency care. No previous studies were found investigating active heat supply from underneath in relation to experiences of thermal comfort and reactions to cold stress in prehospital emergency care. The patients’ own experiences are important to learn from as it may contribute to knowledge that could improve care and lead to increased thermal comfort for patients, already suffering for other reasons. Studies on patients’ exposure to cold and functional methods for reaching thermal comfort are therefore needed in prehospital emergency care.

## **Overall aim**

The overall aim is to investigate patients' experiences of thermal comfort and reactions to cold exposure in prehospital emergency care and to evaluate the effects of an intervention using active warming from underneath.

### **Specific aim**

**I** To explore patients' experiences of being cold when injured in a cold environment.

**II** To investigate injured and ill patients' experiences of cold exposure and identify related factors during ambulance care.

**III** To evaluate the effect of a heated ambulance mattress-prototype on body temperatures and thermal comfort in an experimental study.

**IV** To evaluate the effect of an electrically heated ambulance mattress-prototype on thermal comfort and patients' temperatures in the prehospital emergency care.

# Materials and methods

## Overall research design

In this thesis, a combination of qualitative and quantitative methods was used to meet the aims. The studies built on the results from each other. The research process started with an inductive qualitative interview study on patients' experiences of cold when being injured outdoor (study I) and was followed by a field study based on observations in prehospital emergency care (study II). Thereafter a quasi-experimental laboratory study on active heat from underneath was conducted in a cold chamber with young healthy persons (study III). Finally, an intervention study with one group of patients lying on a heated mattress-prototype and a control group lying on a regular stretcher in an ambulance was tested (study IV). The studies are presented in Table 1.

**Table 1. A schematic overview of study I-IV**

<b>Study</b>	<b>Design</b>	<b>Data collection</b>	<b>Participants</b>	<b>Analysis</b>
<b>I</b>	Inductive interview study	Narrative interviews	20 patients injured in a cold environment	Qualitative content analysis
<b>II</b>	Field study	Observation protocols, measurements of vital signs and temperatures	62 patients in prehospital emergency care	Descriptive and comparative statistics
<b>III</b>	Quasi-experimental laboratory study	Observation protocols, measurements of cold discomfort, vital signs, temperatures and participants' short notes	23 healthy young persons inside and outside a cold chamber	Descriptive and comparative statistics Qualitative content analysis
<b>IV</b>	Intervention study	Observation protocols, measurements of cold discomfort and temperatures	60 patients in prehospital emergency care	Descriptive and comparative statistics

## **Study I**

Setting The participants were included in a previous intervention study in the north of Sweden, using either passive or active warming, a chemical heating pad on top of the torso on patients who had been injured in cold environment (Lundgren et al., 2011). This interview study was complementary and focused on the patients' experiences of cold.

Participants A nationwide sample of 20 patients whereof seven had been treated with passive warming, and 13 had been supplied active warming. Background data was taken from the previous intervention study (Lundgren et al., 2011). The patients had moderate to severe injuries. The average age was 49.6 (min 19, max 91, SD= $\pm 20.7$ ). Patients' average core body temperature was 35.5 (min 32.6 max 37.7, SD= $\pm 1.3$ ). The outside temperature ranged from  $-4^{\circ}\text{C}$  to  $-14^{\circ}\text{C}$  and the wind ranged from windless to 10m/s. (c.f. Lundgren et al., 2011), Study I). Inclusion criteria in the interview study were adult persons ( $\geq 18$  years) injured outdoors with a preserved mental status and no need for cardiopulmonary resuscitation. Exclusion criteria were non-Swedish speaking, having been taken indoors for more than 10 minutes before ambulance arrival or having already received active warming.

Data collection The interviews were performed either face-to-face (n=10) at a location agreed to by the participants or by telephone (n=10) lasting 18 to 37 minutes (mean 26 minutes). The participants were asked to narrate the injury event starting from just before the event until arrival at the Emergency Department (ED). The initial question was, "Please tell me about the event when you got injured in the cold environment?" followed by questions such as "Can you describe your experiences of being cold?" At times, the narratives were supported with follow-up questions such as, "Can you explain further?" "What did you experience then?" This was done to clarify the content of the interviews (Mishler, 2005, Sandelowski, 1991). The interviews were recorded and transcribed verbatim.

Data analysis The interview text was analysed using a qualitative content analysis (Graneheim and Lundman, 2004). The study was inductive; meaning the text itself generated ideas for sub-categories and categories. Repeated readings of the whole text led to the identification of meaning units that were condensed while preserving the core content. The condensed text was then abstracted and given codes. The codes were amalgamated and sorted into preliminary subcategories after comparison of the content within and across the text and the codes. In the next step, main categories were formulated based on the text as a whole, the content of subcategories and the interpretation of the underlying meanings (Krippendorff, 2012).

## Study II

**Setting** Research observations were performed in prehospital emergency care during daytime for 22 days from January to March 2011. Mean outdoor temperature during observation days was  $-8.6\text{ }^{\circ}\text{C}$ , ranging from  $+7\text{ }^{\circ}\text{C}$  to  $-5\text{ }^{\circ}\text{C}$ .

**Participants** The study included 62 consecutively selected patients, 34 women and 28 men. Age ranged from 21 to 95 years (mean= 68, SD =  $\pm 22.5$ ). Inclusion criterion for participation was patients,  $\geq 18$  years old. Exclusion criteria were being unconscious or having difficulty communicating. The patients were observed when they were cared for by nurses in the prehospital emergency care in Västerbotten County Council in the north of Sweden. At arrival to the patients, 54 of the 62 were found indoors in room temperature. Background data are presented in Table 2.

**Data collection** After the nurses had examined the patients' vital parameters and assessed the medical history, the observations and the temperature measurement started. Measurements of oxygen saturation, respiratory rate (RR), heart rate (HR), blood pressure (BP), and internal ear temperature as a substitute for core body temperature (T<sub>cb</sub>) (measured with IR Braun ThermoScan Exac Temp IRT 4520, Germany) (Figure 1) were collected by the nurses. The finger temperature (T<sub>f</sub>) (on outer fingertips, left hand), the mattress temperature (T<sub>m</sub>) with an infrared (IR) thermometer (CIR 8819, with dual laser points) and the air temperature with an external thermal sensor (Bead probe 6030) were measured by the researcher. The patients were asked questions in the ambulance, for example, "Do you feel warm or cold?" "Do you experience discomfort from cold?" Observations, for example, of shivering were made and noted in the protocol.



**Figure 1.** The infrared light thermometer with dual laser points.

Analysis Continuous variables were analysed with independent sample t-test, paired sampled t-test and dichotomous variables with cross tabulation, Chi square test, and Fischer's exact test. Standardized effect size was calculated with Cohen's d for parametric data and Phi for non-parametric data.

**Table 2. Background data of those who reported cold (n=27) and those who did not (n=35) (Study II, p. 3)**

	<b>Total</b>	<b>Experience of cold</b>	<b>No experience of cold</b>
	<u>n</u>	<u>n</u>	<u>n</u>
<b>Age (years)</b>			
<59	21	10	11
≥60	41	17	24
<b>Sex</b>			
Male	28	13	15
Female	34	14	20
<b>Observation start</b>			
Indoor	54	22	32
Outdoor	8	5	3
<b>Clothing</b>			
Thin	21	11	10
Medium	31	12	19
Thick	10	4	6
<b>Observation time (minutes)</b>		18	21

### **Study III**

Setting The quasi-experimental laboratory study took place over four days in November 2011, inside and outside of a cold chamber. The cold chamber had a constant temperature (+2 °C).

Participants Of approximately 50 students from the Umeå University, the Department of Nursing 23 agreed to participate; 20 women and three men. The inclusion criteria were healthy students, ≥18 years old. The average participant age was 24, varying between 19 and 46 years old. Exclusion criteria were being pregnant, being a smoker or snuff user, persons who had cold-induced asthma or being medicated with circulation affecting drugs.

The experiment Each participant was exposed to cold in the cold chamber two times in a row on the same day, including pre-, peri-, and post measurements. An observation protocol was used including temperatures and cold discomfort. To measure the patients' subjective thermal status, the Cold Discomfort Scale (CDS) was used. CDS is a subjective judgment scale, ranging from 0 to 10, where 0 indicates not being cold at all, and 10 indicates unbearable cold. The scale is validated by (Lundgren et al., 2013). Four statements from the State-Trait-Anxiety-Inventory (STAI) (Spielberger and Sycleman, 1994), were also distributed. The answers to the four statements from the STAI instrument were estimated from 1–4 where 1 = Not at all, 2 = Somewhat, 3 = Moderately so, and 4 = Very much so. The four statements selected were the most relevant for this study.

Objective measure of vital signs such as respiratory rate (RR), heart rate (HR) and blood pressure (BP), and Body Mass Index (BMI) were measured. Internal ear temperature (T<sub>cb</sub>) was measured with an IR Braun ThermoScan Exac Temp IRT 4520. Back and finger temperatures were measured with an infrared light thermometer with double laser (CIR 8819). RR, HR and BP were manually measured.

Data were collected six times per participant to make comparisons from before being exposed to the cold chamber and after being in the cold chamber, lying in room temperature on a regular ambulance stretcher and the next time on a stretcher with a heated mattress prototype (Figure 2). At the end of the day, the participants wrote down short notes about their experience of the different mattresses used in the trials.



**Figure 2.** The heated mattress applied on the stretcher.

**Analysis** The endpoint finger temperature was estimated to 0.5 °C between trials with a power of 80% with a significant level of 5%. The sample size calculation showed that a minimum of 17 participants was required in each trial. Continuous variables were analysed with Paired-Samples t-Test and Effect Size (Eta Squared), non-parametric data were analysed with Wilcoxon signed rank test and Effect Size (Cohen) to calculate the differences between the trials. The short notes about the experiences of the two mattresses were analysed using qualitative content analysis. The statistical analyses were performed with IBM SPSS software (version 17 SPSS Inc., Chicago IL, USA).

## **Study IV**

**Setting** The patients were observed during prehospital emergency care in Västerbotten County Council in the north of Sweden. Data were collected during November and December 2011 and 2014. The average outdoor temperature during those months was +2 °C and the ambulance transport time averaged 15 min.

**Participants** A total of 60 patients were included in the study, consecutively divided into two groups. Inclusion criteria were patients  $\geq 18$  years old and Swedish speaking. Unconscious patients, patients having communication problems, and patients having severe and life-threatening injuries or illness with extensive care needs were excluded. Background data are presented in Table 3.

**The intervention** In the intervention group the patients (n= 30) received supply of a heated mattress connected to a 12 volt power supply in the ambulance and was constantly on, both during ambulance transport and when the ambulance had no current assignment. The heated mattress generated a surface temperature of approximately +35 °C. The length of the mattress is 150cm (Figure 2). The 30 patients in the control group were transported on a regular stretcher equipped traditionally with a blanket, sheet and a pillow. After the nurses had examined the patients' vital parameters and assessed the medical history, the observations and the temperature measurement started. The patients were asked to rate their experience of cold on CDS. Finger temperatures (on outer fingertips, left hand) were measured with an infrared (IR) thermometer. Internal ear temperature (measured with IR Brown, Exact Temp) was collected in the ambulance by the researcher. The air temperature in the ambulance compartment was measured with an external thermal sensor connected to the IR thermometer. The patients were asked questions in the ambulance, for example, "Do you feel warm or cold?" "Was it warm or cold to lay on the

mattress?” Intervention outcomes were ratings on CDS, finger temperature, observations and answers to the questions.

**Analysis** The sample size calculation showed that at least 22 patients were required in each group. A difference in mean score of CDS ratings between group receiving a heated mattress (intervention) and the group with an unheated mattress (control) was estimated to be 1.5. Standard deviation was estimated to 2.0 (c.f. Aléx et al., 2014) with a power of 80% and a significant level of 5%. Difference in mean, significance level, standard deviation, and effect size were calculated. Continuous variables were analysed with independent sample t-test, and non-parametric data with Friedman Test, Kendall W’s Test, Mann-Whitney U test and dichotomous variables with cross tabulation, Chi square test. Standardized effect size was calculated with Cohen’s d for parametric data and phi for non-parametric data. The statistical analyses were performed with IBM SPSS software (version 21 SPSS Inc., Chicago IL, USA).

**Table 3. Background data and the patients’ reasons to call an ambulance.** (Study IV, p.3)

	<b>Intervention n= 30</b>	<b>Control n= 30</b>	<b>p-value</b>
<b>Age (mean, SD)</b>	76.4 (16.7)	68.3 (16.7)	0.11
<b>Sex (n, %)</b>			
Men	14 (47)	18 (60)	
Women	16 (53)	12 (40)	
<b>Reasons to call an ambulance</b>	<b><u>n (%)</u></b>	<b><u>n (%)</u></b>	
Respiratory insufficiency	3 (10)	2 (7)	
Cardiovascular symptoms	10 (33)	12 (40)	
Severe illness	5 (17)	4 (13)	
Trauma	4 (13)	5 (17)	
Pain	5 (17)	2 (7)	
Fainting	2 (7)	2 (7)	
Abdominal pain	1 (3)	3 (10)	

## **Ethical considerations**

The process in this thesis is in accordance with the principles outlined in the Declaration of Helsinki (The World Medical Association, 2008) and all studies were approved by the Regional Ethics Committee in Umeå, (Dnr 07-145 M for study **I**, Dnr 2010-391-31M for study **II** and Dnr 2011-343-31M for studies **III** and **IV**).

In all studies (**I**, **II**, **III**, **IV**) the participants were informed that participation was voluntary and of their right to withdraw at any time without explanation. They had to voluntarily consent to participate. They were also informed that their confidentiality would be assured throughout the research process.

Information about study **I** was provided to the participants by a letter with a request to participate. If they chose to participate, informed consent was given by phone or e-mail. The interviews began with information about the aim of the study.

In studies **II** and **IV**, oral information about the research study was given after the preliminary assessment phase and the patients gave their consent to participate. Participants in study **III** received oral and written information.

Ethical concerns arose during the project because of difficulties doing research in prehospital emergency care, for example, the issue of burdening already vulnerable patients in complex situations. When asking critically ill patients suffering from severe pain and anxiety about their experiences of cold, it sometimes felt as though it were a burden, especially when they were acutely ill in their homes at room temperature and the information about the study seemed to be of minor importance at the moment. However, it did not change my mind about the importance of continuous data collection. The research did not introduce any risk for the patients. Instead, patients who received the supply of active warming from underneath experienced it as beneficial, and it increased their thermal comfort.

# Results

The results in this thesis show that being injured outside in a cold environment and having to lay down on the cold ground is devastating (I) and the ambulance patient compartment is too cold to offer thermal comfort (II). The heated mattresses used in studies III and IV have a positive impact on thermal comfort, back temperature, and physiological aspects.

## Study I

Patients described that a short while after the trauma they suffered more from the cold than from the pain of the injury. The air temperature in the ambulance compartment was not sufficient to offer thermal comfort. Patients who received active heat supply experienced it in a positive way. Two categories were formulated and are illustrated here with examples of patients' quotations:

1) Enduring suffering included experiences of a) becoming cold expressed by a patient as: “..I was cold down to the bone marrow; lying in the snow and it was +6-7 degrees...it was windy and I was only wearing jeans so the cold went right in under my skin. It made it impossible for me to relax... you just lay down and shivered”, b) having pain described as: “The cold made the pain more intense... I couldn't relax... I was very, very tense”, c) shivering expressed as: “I tried to relax as much as I could but sometimes the shivering was too strong because of the cold... as soon as the muscle moved it hurt a lot”.

Finally, enduring suffering also included thoughts of dying of the cold. The cold from below was described as dreadful, and the cold was creeping through the body into the bones. They were in desperate need of heat and help. It was frustrating to shiver, and they felt a lack of control and it aggravated the pain, especially for those having fractures. The cold became their primary problem.

2) Relief of suffering included experiences of becoming warm and increased comfort: “They turned the heat on in the ambulance... the heat returned quite fast in the ambulance, but I froze anyway”. The active warming was described as warmth spreading throughout the body. It stopped the shivering and provided comfort: “...when I got the heat supply from the people that were there and took care of me, I think it meant as much as receiving the right medicine or what can I say”. In combination with pain relief, the patients could finally relax.

## Study II

Of the 62 included patients, 52 (85%) had a finger temperature below the comfort zone (31 °C) in the ambulance and 27 patients (44%) experienced the ambient temperature in the patient compartment in the ambulance to be cold. Among the 54 patients that were indoors when the ambulance arrived, there was a significant decrease in finger temperature between measurements of temperature indoor at arrival (mean=28.4, SD=± 4.47) to measurement in the ambulance compartment (mean=25.2, SD=± 5.08; p= 0.001, ES=0.66). At arrival to the patient, the surface temperature on the ambulance stretcher ranged between -11 °C and 24.3 °C and at the ambulance the surface temperature ranged from -22.3 to 8.4. °C (Table 4). Of those who reported being cold in the ambulance compartment compared to those who did not, there was a significant difference concerning the mattress temperature, shivering, and thermal discomfort from cold (Table 5). There were no significant differences between the two groups regarding Tcb, vital parameters, (O2 level, RR, HR or BP).

**Table 4. Mattress, air and patient finger temperature at baseline, in the ambulance and at the emergency department (n=62) (Study II p. 4)**

	<u>Baseline</u>			<u>Ambulance</u>			<u>ED</u>		
	<u>Min</u>	<u>Max</u>	<u>Mean</u>	<u>Min</u>	<u>Max</u>	<u>Mean</u>	<u>Min</u>	<u>Max</u>	<u>Mean</u>
<b>Mattress</b>	-11.0 <sup>3</sup>	24.3 <sup>3</sup>	14.3 <sup>3</sup>	-22.33	8.4 <sup>1</sup>	-3.9 <sup>4</sup>	-3.3 <sup>4</sup>	22.1 <sup>4</sup>	14.1 <sup>4</sup>
<b>Air</b>	-22.9 <sup>3</sup>	25.5 <sup>3</sup>	17.2 <sup>3</sup>	5.2 <sup>1</sup>	27.1 <sup>1</sup>	18.7 <sup>1</sup>	12.3 <sup>2</sup>	25.3 <sup>2</sup>	19.9 <sup>2</sup>
<b>Finger</b>	11.4	37.8	27.6	12.0	36.3	25.0	15.4	37.8	26.1

<sup>1</sup> 3 missing, <sup>2</sup> 6 missing, <sup>3</sup> 1 missing, <sup>4</sup> 2 missing,

**Table 5. Comparison between the group who reported being cold (n=27) in the ambulance compartment and those who did not (n=35)**

	<b>Total</b>	<b>Experience of being cold</b>	<b>No experience of being cold</b>	<b>p-value</b>	<b>ES</b>
<b>Cold mattress</b>					
Yes	14	12	2	0.001	0,46
No	48	15	33		
<b>Shivering</b>					
Yes	15	9	6	0.018	0,34
No	47	5	42		
<b>Thermal discomfort from cold</b>					
Yes	14	14	0	0.001	0,62
No	48	35	13		

Effect Size (Phi): 0.1=small effect, 0.3=medium effect, 0.5=large effect.

### Study III

There was a significant increase and a large effect size in back temperatures between the trials of the heated mattress and the trial with the regular mattress. It was also a significant decrease concerning the statement “I am tense” ( $p=0.011$ ,  $ES=0.37$ ) and a significant increase in participants rating of the statement “I feel comfortable” ( $p= 0.012$ ,  $ES=0.37$ ), “I feel content” ( $p=0.008$ ,  $ES=0.39$ ) and “I am relaxed”, comparing the heated mattress trial with the regular mattress trial. There was no significant difference between trials concerning finger or ear temperature or the CDS (Table 6). The short notes in the qualitative analysis resulted in four categories presented with examples of patients’ quotations.

- 1) Being warm and comfortable: The heated mattress was expressed as pleasant and comfortable and warm, especially on the thighs and back. The heated mattress was also experienced as warming up the whole body.

*“The stretcher felt immediately warm and the heat spread out through the body. After a short while, the body was warm again” .*

- 2) Providing security: It was expressed that the heated mattress imparted a feeling of safety.

*“I felt secure when embedded on the stretcher”.*

- 3) Being unrelaxed: The unheated mattress was difficult to relax on due to the cold surface.

*“It was more difficult to relax on the unheated mattress”.*

- 4) Not being warm: It took longer time to retain heat after lying on the unheated mattress compared to the heated mattress.

*“It felt good to have a blanket but the heat took time to return”.*

**Table 6. Difference in mean\* of back temperature, cold discomfort scale (CDS) and finger temperatures between the heated mattress trial (n=23) and the unheated mattress trial (n=23) (Study III p. 4)**

	<b>Unheated mattress trial</b>	<b>Heated mattress trial</b>			
	Mean (SD)	Mean (SD)	Difference in mean (%)	p-value	ES
<b>Back temperature (°C)</b>	12,0 (2,98)	14,4 (3,70)	2.4 (20,0)	0,009 <sup>~~</sup>	0.27 <sup>~</sup>
<b>Ear temperature (°C)</b>	0,05 (0,42)	-0,01 (0,34)	0.04 (-20)	0,646 <sup>~~</sup>	0.00 <sup>~</sup>
<b>Finger temperature (°C)</b>	8,9 (5,15)	8,2 (5,31)	0.7 (8)	0,867 <sup>††</sup>	0.35 <sup>†</sup>
<b>Cold Discomfort Scale (CDS)</b>	-3,5 (1,73)	-4,2 (1,78)	0.7 (20,0)	0,063 <sup>††</sup>	0.38 <sup>†</sup>

\* Difference between having spent 10 minutes in the cold room and then lying on the stretcher 10 minutes. A negative value denotes a decrease.

<sup>~~</sup> From Paired-Sample t-Test

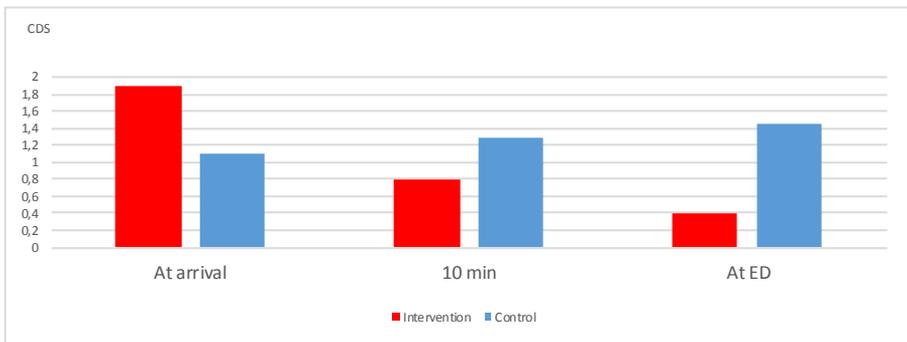
<sup>~</sup> Effect Size (Eta Squared) 0.01= small or no effect, 0.06=moderate effect, 0.14 large effect

<sup>††</sup> From Wilcoxon signed-rank test

<sup>†</sup> Effect Size (Cohen) 0.1=small effect, 0.3= medium effect, 0.5 large effect

## Study IV

The difference in CDS ratings between the first measurement at arrival to the patient and the last measurement at arrival to the ED differed significantly between groups ( $p=0,001$ ,  $\Phi=0.57$ ). In the intervention group, the thermal comfort increased during the ambulance care compared to a decreased thermal comfort for the control group (Figure 3). A significant higher proportion of the participants rated the mattress as cold to lie down on in the control group (57%) compared to the intervention group (3%) ( $p<0.001$ ,  $\Phi=0.58$ ). There were no significant differences regarding the participants rating of the back as warm or cold, after 10 minutes in the ambulance compartment, 100% in the intervention group and 93% in the control group rated their back as warm ( $p=0,492$ ,  $\Phi=0.15$ ).



**Figure 3.** CDS measurement for intervention and control group at arrival to the patient, after 10 min and at arrival to ED. Friedman Test, Kendall W's Test: Intervention ( $p<0.001$ ), Control ( $p=0.014$ ). (Study IV p. 3)

A significant difference in mean in CDS was found between the measurement at arrival to the patient and the measurement at arrival to the ED between groups. The mean difference in the intervention group showed a decrease in CDS ratings ( $-0.93$ ,  $SD=\pm 0.50$ ), that is experiences of being warmer. The control group showed an increased rating of CDS, that is experiences of being colder ( $1.43$ ,  $ED=\pm 0.51$ ;  $p<0.001$ ;  $ES=0.57$ ). No significant difference between groups was seen in mean finger temperatures or mean core body temperature.

# Discussion

The overall aim of this thesis was to investigate patients' experiences of thermal comfort and reactions to cold exposure in prehospital emergency care and to evaluate the effects of an intervention using active warming from underneath. The overall results show that the use of active warming prevents further heat loss, decreases cold stress, and increases thermal comfort.

## The environment in prehospital emergency care

There is no doubt that many of the patients included in this thesis were exposed to cold stress related to a cold environment (studies **I**, **II**, and **IV**), even if only a few were hypothermic. Levine's Conservation Model is based on the fundamental interaction of individuals with their environments. A comfortable environment is needed to give holistic care (Levine, 1967). In nursing, people are seen as responding holistically to complex stimuli (Kolcaba and Wilson, 2002), such as cold exposure. The preferred room temperature to maintain thermal comfort has been shown to be 24.6 °C (Verheyen et al., 2011). The results show that patients reacted to the cold before and during the ambulance transport (studies **I**, **II**, and **IV**). A majority in study **II** was exposed to an air temperature in the ambulance compartment of less than 24 °C and at the coolest 5.2 °C. Nearly half of the patients in study **II** experienced the patient compartment as cold. At arrival to the patients, surface temperature on the ambulance mattress ranged from -11 °C to 24.3 °C (mean = 14.3 °C) and at the ambulance temperature ranged from -22.3 °C to 8.4 °C (mean = -3.9 °C), indicating that the mattress quickly adapted to the cold environment. For patients in prehospital emergency care experiencing cold stress, it is difficult to influence their situation when exposed to cold because they are unable to produce heat by themselves. Meriläinen et al. (2010) state that patients are indirectly affected by the environment, but are often unable to influence it. One fourth of the patients in study **II** reported that the regular stretcher was cold to lie down on and it seemed that the stretcher was an important aspect in cooling the patients and their experience of cold. This assumption is in line with Zhang et al. (2004) stating that cooling of the back is one of the leading influences of thermal sensation. Offering a cold mattress in the ambulance is unwarrantable when there is knowledge that prevention and early interruption of cold stress is important as hypothermia is an independent predictor of morbidity and mortality (Thomassen et al., 2011).

It seems, in the results from this thesis (Studies **II**, **IV**), as if the patients themselves warmed the stretcher with their own heat. This assumption is

supported by the second law of thermodynamics which states that heat spontaneously flows from a hot body to a cold body (Parsons, 2014). In study **I**, it was expressed that raising the temperature in the patient compartment of the ambulance did not impart major benefits to the patient. The air temperature quickly returned to normal in the ambulance compartment, but the patients still felt cold. Raising the room temperature for cold patients is not effective because air is a poor conductor via convection of energy when compared to heat conduction from warm surfaces (Tsuei and Kearney, 2004). In wintertime, when opening the doors of the ambulance, the air temperature in the ambulance decreases quickly. To counteract the heat loss, the heater is set to high. Even so, warm air rises and the patient lies on a stretcher embedded with polyester blankets without direct contact with the warm air, that is, no benefit for the patients.

## **Reactions to cold stress**

The mean finger temperature decreased from arrival to the patients (outdoor patients excluded) to measurement in the ambulance compartment indicating a vasoconstriction due to cold stress (**II**). Under warm conditions skin temperature ranges from 35 to 37 °C and cold sensation increases rapidly when skin temperature falls below 33.5 °C (Gagge et al., 1967). When a person's whole body thermal sensation is neutral, the finger temperature is between 28-36 °C (Wang et al., 2007). One cause of decreased finger temperature is contact with cold surfaces affecting the skin temperature. For comparison, an experimental study on participants having contact with cold surfaces showed a rapid decrease in skin temperature because of conduction, leading to thermal discomfort and cold stress. When bare skin contacted nylon material at 10 °C, the skin temperature dropped to 15 °C in approximately 30 seconds and at -15 °C the skin temperature fell to 15 °C in 4.5 seconds (Geng et al., 2006).

It is well known that pain and fear can contribute to vasoconstriction and cold fingers, but in studies **II** and **IV** nurses attempted to decrease the patients' pain level using pain relieving substances. The nurses acted in a way that likely reduced the patients' fear. Interaction with professionals can provide calmness (Elmqvist et al., 2008). Even if some patients are exposed for only a short episode of hypothermia, vasoconstriction effects can persist for hours after the core temperature has been normalized (c.f. Kurz et al., 1996, Sessler, 1997). The explanation for why no significant differences in finger temperatures were seen between the trials in study **III**, or between the intervention group and the control group in study **IV**, may be because the effects of vasoconstriction can last for hours. The decision to measure finger temperatures in studies **II-IV** was in the hopes of showing that the heated

mattress would result in a significant increase of finger temperature between groups. However, there was no significant difference in finger temperature or core body temperature between the intervention group and the control group in studies **III** and **IV**. More studies with, for example, a larger sample size performed over an extended period are perhaps needed to verify significant differences.

In study **I**, patients were lying on a cold surface, and the cold was experienced as creeping under the skin into the bones and made them suffer from the cold exposure. Some patients experienced shivering caused by the cold. In study **I**, shivering was described as one of the worst experiences at the injury event due to the loss of body control. Shivering was experienced as devastating; especially for those who had fractures which is in line with the findings by Kober et al. (2001) who discuss that shivering can contribute more pain, especially before the fracture is immobilized. Research about patients' experiences of shivering is scarce, but shivering has been shown to increase a sense of discomfort in postoperative settings (Liem and Aldrete, 1974, Vogelsang, 1994).

A common cause of cold exposure for old people occurs from lying on the floor, for example, after a fall. Decreased mobility levels and cold exposure from ambient temperatures convey cold skin and body temperature leading to discomfort (Farley and McLafferty, 2008). Old people have a lower metabolic rate (Fanger, 1973), and Olofsson et al. (2007) state that many old patients are malnourished when they arrive at the hospital. It has been shown that food intake has to be increased to improve the metabolic rate and compensate for excessive heat loss to maintain body temperature. For old, undernourished patients who then become ill or injured, lying on a cold stretcher might be devastating, allowing essential energy to flow to the cold stretcher. According to Levine (1991), active warming is one way of contributing to the conservation of energy, which is important to the patients' healing process.

### **Active warming interventions**

In study **III**, the back temperature increased in the intervention group compared to the control group. Likewise, Engelen et al. (2011) state that active warming conserved core body heat better than passive warming. However, there was no difference in core body temperature between intervention and control groups in studies **III** and **IV**. These results are in line with Williams et al. (2005), showing no significant differences in re-warming rates seen in their forced air warming group (Bair hugger) compared to the passive warming group (polyester blanket), after water

immersion. In contrast, Watts et al. (1999) state that hot pack rewarming on patients (n=12) during transport to the hospital was effective in maintaining the core body temperature compared to patients treated with passive warming (n=9). The hot packs appeared to raise core body temperature. Greif et al. (2000) show that active warming blankets more than doubled the rewarming rate compared with rewarming produced by reflective metal foil. Further, Sessler and Schroeder (1993) show that the body core rewarming rates were significantly faster in patients assigned to forced-air rewarming from above the patients compared to those given blankets. A study by Nguyen et al. (2010) states that cutaneous warming with an underbody warming system is a feasible and effective method to prevent intraoperative hypothermia during laparoscopic gastrointestinal surgery. Recently published research has shown that head warming is as effective as torso warming for rewarming hypothermic patients. If removal of the insulation and exposure of the torso are contra-indicated due to the environment, head warming may be the preferable method of rewarming in the field (Sran et al., 2014). Pu et al. (2014) showed that an underbody warming system is feasible and efficient in maintaining patients' normal temperature during surgery. To some extent, patients cared for in the prehospital emergency care are admitted directly to operating units; therefore, it may be important that the patient arrive with a more normal temperature.

Unless hypothermia is specifically indicated, (e.g., for protection against ischemia), the intra-operative core temperature should be maintained above 36 °C (Sessler, 1997). An in-hospital study on surgical wound infections showed a prolonged duration for hypothermic patients compared to normothermic patients (Kurz et al., 1996). Likewise, patients whose temperatures have been maintained at normal levels during the intra-operative period experienced fewer adverse outcomes, and their hospital cost were lower (Brown, 1999). It is shown that hypothermic patients have longer hospital stays compared to normothermic patients (Kurz et al., 1996). Melling et al. (2001), demonstrated that both local and general pre-warming for 30 minutes using a forced air warming blanket reduced the risk for wound infection after clean surgery from 14% to 5%. It was also found that patients who received no extra perioperative heat needed a 20% longer hospital stay than those who received extra perioperative heat in the form of a hot-air blankets and warm fluids intravenously (Brown, 1999). Preoperative warming provides comfort, decreases anxiety, and prevents postoperative complications (Wagner et al., 2006). Melling et al. (2001), conclude that preoperative warming may be an alternative to the controversial use of antibiotics, avoiding the associated risks of bacterial resistance in clean surgery. For patients, the benefits of using active heat from underneath, as shown in this thesis, may start in the ambulance.

Based on the results in this thesis, in combination with research on active warming and knowledge of the negative consequences of cold stress, there is a need for greater focus on patients' temperatures and thermal comfort. Routines must be developed and implemented in prehospital emergency care and a precondition for that is the implementation of active warming. A change of the outer climate is not possible and living in subarctic regions of the world implies the acceptance of living in cold environments during periods of the year. The exposure to cold and, thereby, lack of a thermoneutral milieu has to be compensated for starting in prehospital care with active heat preferably supplied from underneath. In study **III**, it was expressed that the heated mattress was warm, comfortable, provided security, and was easier to relax on. Grief et al. (2000) conclude active warming is, therefore, useful in the prehospital emergency setting.

### **Active warming and thermal comfort**

Thermal comfort increased when providing active heat from underneath compared to decreased thermal comfort in the control group during transport (Study **IV**). The patients who received active warming in studies **I** and **III** expressed feelings of calmness and security allowing them to lie down and begin to relax. Active warming meant as much as receiving the right medicine (**I**). Kolcaba's theory describes human beings as having a holistic response to complex stimuli, such as cold exposure. Offering active warming to patients experiencing cold, improves comfort. Comfort is a desirable holistic outcome that is relevant to the discipline of nursing (Kolcaba, 1994). Comfort is defined as the satisfaction (relief, ease, transcendence) of the care for needs that are stressful for patients. Wagner et al. (2006) state that in numerous studies thermal comfort is not defined, but addresses cold as an uncomfortable sensation that increases restlessness, aggravates pain, and decreases overall patient comfort. Results regarding thermal comfort in the present thesis are in line with other studies on thermal comfort. A study by Robinson and Benton (2002) showed that older hospitalized patients reported less discomfort in terms of pain and displeasure related to the cool environment when given active warming (pre-warmed cotton blankets) compared to passive warming (non-warmed blankets). Those who were unable to communicate showed fewer nonverbal behaviors indicating discomfort.

Results in this thesis are also in line with a randomized pre- and post-study including 118 patients in a perioperative setting which showed that patients who underwent preoperative treatment with active warming blankets had less anxiety and an increased thermal comfort compared to patients in the control group. Further, an experimental study (six participants participated

in four trials each) using pre-warmed and un-warmed cotton blankets in hospital settings showed that the heated blankets reduced the heat loss 9-16W more than the un-warmed ones. However, the benefit disappeared after 10 minutes (Sessler and Schroeder, 1993). That result is in line with a study by Bujdoso (2009) showing that all the blankets used in the study (43-66 °C) adapted to the room temperature within five minutes and, therefore, are relatively ineffective unless another heated blanket was applied. As far as I have seen, there is only one study on warming blankets in prehospital care measuring anxiety and satisfaction related to thermal comfort. A study of 90 participants with minor trauma who received active warming blankets in the ambulance markedly reduced the patients' anxiety, pain, and improved the satisfaction compared to passively warmed patients (Kober et al., 2001).

### **Active warming from underneath**

One advantage of using the heated mattress in this thesis is the constant effect of the heated mattress when connected to an electrical source. In the work of developing and improving the mattress-prototype, it was decided to set the temperature to 35 °C. This temperature seems to improve thermal comfort for several groups of patients and was not too warm to risk heat injuries. Skin temperature must reach between 47-48 °C to achieve cellular damage (Moritz, 1947). When the nurses in prehospital emergency care must remove patients' clothes for examination of the patient, for example, inspection of thorax or applying electrodes to measure ECG, the active heat supply on top of the patient, if used, needs to be removed. When active warming from underneath is used, it does not have to be interrupted and there is less risk of heat energy loss for the patients. The heated mattress, compared to heating pads affects a larger area of the patient's body surface. The greater area that is affected by heat or cold, the more intense the sensation will be felt. Watts et al. (1999) discuss that most treatments of active warming are reserved for the "coldest of the cold". An advantage with the heated mattress is that it can constantly be used on the stretcher for each and every patient preventing cold stress. Kolcaba (1991) states that it is of value when nursing is demonstrated by removing the source of discomfort before the patient experiences discomfort. Intervention studies measuring comfort to meet specific patient needs are necessary (Kolcaba, 1991).

## **Lack of thermal comfort**

From the present thesis, one can learn that when no thermal comfort is offered to the patients it can be viewed that the patients suffer from lack of caring. Suffering from the lack of adequate care is the result of patients suffering from insufficiency and or shortcomings in the caring situation (Eriksson, 1994). Eriksson describes three areas of suffering: from illness, from life, and suffering from caring. Further, she states that suffering is natural in life, but it does not have meaning in itself, which means that nothing good comes from suffering in itself. One way of diminishing patients' suffering from caring is to prevent cold discomfort and hypothermia. Nursing care includes assessments of patients' needs that require the caregiver to be competent in nursing, medical practice, and science. Nursing and medical science must be seen as complementary and not as conflicting (Wireklint Sundström and Dahlberg, 2011). The nurses in prehospital emergency care treat the patient in many effective ways, but maybe not adequate enough to provide the thermoneutral environment needed to improve the patient's own capacity to reach health and wellbeing, helping them restore a normal body temperature. Unfortunately, there is a lack of functional warming equipment in prehospital emergency care, and there seems to be no information regarding the availability of active warming in prehospital emergency care in Sweden. However, in Norway, it is reported that that 11% of all ground ambulance services had active warming (chemical heat pads) (Karlsen et al., 2013).

## **Implementation of research in practice**

Results from studies **III** and **IV** show that the heated mattress can improve the nursing care for patients. Worldwide, only a small proportion of new knowledge is adopted into practice, and often at an unreasonably slow pace (Grol et al., 2013). These shortcomings are threats to the health and wellbeing of patients (McGlynn et al., 2003) and to the development of good nursing care. The gap between research and practice can lead to loss of potential health benefits in the population, a suboptimal delivery of nursing care, and a waste of already limited health care resources. The 'Know-Do' gap is identified by the WHO as one of the main challenges for public health in the 21<sup>st</sup> century (WHO, 2005). Research results need to be heard, be visible, and influence caring based on the new knowledge that has emerged within the discipline. Research is expected to lead to innovation and Hallberg (2006) criticizes nursing researchers for not implementing research in practice. Research in the present thesis has led to a limited implementation of the heated mattress in Västerbotten County Council, which may increase the health benefits for patients.

If identifying an aspect of comfort and if interventions are targeted toward specific needs, it is a way of moving negative tension in a positive direction (Kolcaba, 1994). Kolcaba stated and hoped that this approach could inspire nursing researchers to design studies with comfort as an outcome (Kolcaba, 1991).

The importance of the results in this thesis are linked to the theoretical frames by Levine (1967), and Kolcaba and Kolcaba (1991). Levine's theory includes the importance of preventing further energy loss; supporting the conservation of energy that will help in the patients' physical healing (Levine, 1967). Levine (1991) further states that the goal of nursing care is to recognize, assist, promote, and support adaptive responses that benefit the patient. From a nursing perspective, it is useful to understand the importance of conserving energy by increasing thermal comfort for patients. The results in this thesis contribute to an increased knowledge about the possibility of recognizing, assisting, promoting, and supporting responses from cold exposure by offering patients' active heat from underneath in prehospital emergency care. The results can be useful in hospital and other similar prehospital care contexts in cold environments. In Kolcaba's Comfort Theory, three types of comfort are described by Kolcaba and Fisher (1996): relief, ease, and transcendence. Reaching the state of transcendence (when a patient rises above problems and pain) by using active heat supply such as a heated mattress is unlikely to occur because there are other stressors in addition to cold stress for patients in prehospital emergency care. However, it seems that active warming has an impact on what Kolcaba calls *Relief* (a specific need is cared for) and *Ease* (experiences of calm and contentment) of patients' cold stress. The patients had specific needs met when given active warming, and they felt an increased calmness and contentment because of increased thermal comfort. Preventing cold stress and increasing thermal comfort for patients in prehospital emergency care may contribute to more holistic care for patients exposed to cold.

# Methodological considerations

The studies in this thesis have various designs and methods. In study **I** interviews were used, study **II** was an explorative field study, study **III** a quasi- experimental study, and study **IV** an intervention study. Therefore, the methodological considerations are discussed for each study separately but some similar parts are presented together. During the entire research process, I have been involved in all stages of the studies. The pre-understanding from my professional work as a specialized nurse in prehospital emergency care has more or less influenced me during the research process. It has been important to be aware of and continually reflect on my pre-understanding. In study **I**, the pre-understanding was kept aside as much as possible, whereas in studies **II-IV** the pre-understanding has been advantageous for developing the designs of the various studies; aiming to increase thermal comfort in prehospital emergency care.

## Study I

A qualitative research design was used as it seemed to be an appropriate method when knowledge is limited of the study topic (Morse and Field, 1996). The goal of most qualitative research is to provide a rich understanding of the human experience through the study of specific cases (Polit and Beck, 2010). Collecting data through interviews is an appropriate method to find out, for example, the experiences (Sandelowski, 2000) of cold exposure. Trustworthiness should be gained through discussions about the analysis to avoid over-interpretations (Graneheim and Lundman, 2004). In the analysis, more than one researcher was involved in the process resulting in the most likely interpretation emerging. The analysis has also been discussed in seminars. It has been ensured that the coding and categories were in line with the meaning units and with the text as a whole. The procedure was repeated to refine and validate the chosen structure (c.f. Graneheim and Lundman, 2004). The internal logic and consistency are also verified by quotations from the text (Study **I** p. 45) and increases trustworthiness and transferability (c.f. Polit and Beck, 2013).

A well-known risk of retrospective studies is recall bias. In study **I**, the interviews were conducted two months to one and a half years after the injury event which might have influenced the patients' memories. The extended time can be seen as a weakness in the study. However, in a study on disaster experiences, it was concluded that the time elapsed between the event and the study had a small effect on what was recalled by the participants (Grimm et al., 2014). In study **I**, it was assumed that the

patients' injury events were extra ordinary situations and, therefore, difficult to forget. The patients in this study all remembered their experiences of feeling cold; hence, the credibility of this study is high.

## **Study II**

The observations were performed in a manner that interactions with the patients were kept to a minimum. The focus was to measure the air and mattress temperatures that the patients were exposed to and patient finger temperatures. Additionally, questions concerning the patients' experience of cold were asked. One of the results showed that patients' experienced the ambulance compartment as cold, without reporting thermal discomfort. A weakness in the study was that the CDS was not used. The CDS probably would have given a better understanding of the patients' experience of thermal discomfort than the two dichotomous questions did. However, the study highlighted the various temperatures that patients are exposed to and the patients' experiences of cold in the ambulance compartment. The weaknesses have to be taken into account when further studies are planned.

## **Study III**

The quasi-experimental study, data were collected inside and outside a cold chamber. A disadvantage was that the cold stretcher in the experiment was not really "cold" as it was placed at room temperature. If there had been a possibility to place the ambulance stretchers inside the cold chamber the difference between the mattresses might have been more obvious. The significant differences between trials may have been larger had there been a larger sample size or if the time in the cold chamber had been extended. The participants only had approximately 15 minutes to recover to their baseline level of finger temperatures and thermal comfort before repeating the cold exposure. The participant had to gain heat by jumping around in winter clothes in the warm room close to the cold chamber. At the initial baseline measurement, some participants stated they always had cold fingers, which also influenced the measurement at second baseline. The result may have been different had there been more time to rest before and between the two trials. However, the limited time for access to the small cold chamber made it impossible. One advantage of the study was that many confounding factors could be eliminated, for example, variations in temperature, wind, snow, and rain. The participants are considered to be a homogenous group, and they wore the same type of clothing during the experiment. Experiments are not frequently used in nursing research but add a valuable perspective. However, there are critics arguing that there is a risk of overestimating the strength of

the results. Even if this study has some limitations, the choice of method seems relevant, and the validity of the study is considered good.

## **Study IV**

The patients in the intervention study were consecutively selected. Shadish et al. (2002) discuss that the majority of quantitative studies with human beings do not involve random samples especially in interventions studies. Intervention research with stringent exclusion criteria increases the internal validity. However, the external validity can be less useable, contributing to difficulties to apply the results in practice (Polit and Beck, 2010). Pragmatic clinical trials when striving to achieve a balance between internal and external validity are asked for (Borglin and Richards, 2010). Because it was a heterogenic group of patients, comparable to the patients usually cared for in the prehospital emergency care, the result ought to be somewhat generalizable to similar contexts.

## **Analyses**

The statistical analyses in studies II-IV have been appropriate to answer the different aims and research questions. Due to few participants, the effect size was calculated. The effect size is an appropriate method to understand the clinical significance of the results (Kelley and Preacher, 2012). The results as a whole and the significant effect size in these studies have clinical importance.

The infrared light thermometer used in Studies II-IV to measure air, finger, back, and mattress temperature has a restricted range including dual laser points and a high sensitivity. The thermometer is easy to use which also increases the reliability. The tympanic-membrane thermometry has proven to be a worthwhile method to measure core body temperature (Helm et al., 1995). Studies validating tympanic-membrane measurement are contradictory, the ear temperature has been criticized to not be an adequate reflection of the core body temperature (Sund-Levander et al., 2004). However, Rotello et al. (1996) show that tympanic measurement is equal to rectal temperature. In another study, it was shown that tympanic-membrane measurement is equal to both esophageal and bladder temperatures and is, therefore, relevant to use in prehospital emergency care settings (Hasper et al., 2011). The CDS has shown to be both a reliable and valid scale when tested on 22 healthy persons that performed two consecutive trials (test-retest) (Lundgren et al., 2013). The scale has shown to be a good instrument to be used in prehospital emergency care. Despite the generally accepted principles not to divide instruments the four chosen STAI statement was

found to be relevant to the study topics and more useful than the total instrument. It can be recommended to use the CDS instrument, the chosen statements from the STAI, the thermometers, patient field notes, and interviews in further research on thermal comfort.

Nursing practice is unavoidably tied to human interactions and experiences where precise and firm conclusions are often not possible (Sitzman and Eichelberger, 2010). In line with what Polit and Beck (2010) argue, I have tried to provide high-qualified descriptive information about the setting, study participants, and analysis processes. Readers can then decide if the results are transferable and generalized to other prehospital emergency contexts with similar groups of people or settings.

Studies **I**, **II**, and **IV** might have questionable internal validity due to the heterogeneous groups concerning patients' age, diseases, injuries, reasons for requesting an ambulance and time spent in the ambulance. The results in these studies might seem obvious but conducting research in prehospital emergency care has shown complexity. Despite that, the patients were more or less acutely ill or injured, confounders that can interact with the reactions to the cold experience are countless, for example, diseases, fear, pain, medications, BMI and time of exposure. However, the included patients in studies **I**, **II**, and **IV** give a relevant picture of the kinds of patients cared for in prehospital emergency care. Therefore, it seems possible to generalize the results in studies **II** and **IV** to other contexts, such as prehospital emergency care, mountain rescue teams, and rescue teams at sea. Also, the findings in study **I** are considered transferable to other contexts where patients are exposed to cold. In study **III**, due to the exclusion criteria and the absence of pain and fear, some factors that affect reactions to cold were eliminated. The participants considered themselves to be healthy without the influence of disease, alcohol, or medication. Young and healthy students experienced thermal discomfort, and injured or sick patients irrespective of age may have an even worse experience of thermal discomfort when temperature decrease. Even so, the knowledge gained from the results in study **III** can be advantageous to prehospital emergency care contexts. Richards and Hamers (2009) argue that nursing science needs innovative research, comparable to study **III**.

In the present thesis, it was found to be valuable to use both quantitative and qualitative methods to provide a more comprehensive picture, which also is highlighted by others (Pluye et al., 2009). The subjective findings from the interviews, ratings on the CDS, and ratings on the STAI statements, combined with the objective measurement of the air, back, finger, and ear temperatures have given a broad picture of the topics studied. The methods

have contributed to more knowledge about patients' thermal discomfort when exposed to cold environments in prehospital emergency care and how thermal comfort increases with active heat supply from underneath.

## **Conclusion, clinical implications, and further research**

The winter climate of northern Sweden is cold and cold exposure in prehospital emergency care is common for ill and injured patients. The ambulance milieu is too cold to provide thermal comfort, and the patients immediately react to cold with experiences of thermal discomfort and decreasing finger temperature, that is, the beginning of a cold stress reaction. Cold stress is devastating for ill and injured patients. Heat supply seems to be an easy and important nursing intervention for injured and sick patients in prehospital emergency care as the heat energy loss needs to be compensated. This thesis shows that heat supply from underneath increases thermal comfort and might prevent cold stress and hypothermia. A heated mattress can contribute to a concrete positive change for patients exposed to cold environments, and it is an important nursing intervention. The decreased amount of stressors contributes to the possibility that patients may get better holistic care when involving the fundamental needs of heat and comfort. The clinical implementation of the heated mattress has started but needs to continue. Further research on preventing cold stress and increasing thermal comfort for patients in various environments such as in prehospital emergency care is needed.

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# References

- AITKEN, L. M., HENDRIKZ, J., DULHUNTY, J. & RUDD, M. 2009. Hypothermia and associated outcomes in seriously injured trauma patients in a predominantly sub-tropical climate. *Resuscitation*, 80, 217-223.
- ALÉX, J., KARLSSON, S. & SAVEMAN, B.-I. 2014. Effect evaluation of a heated ambulance mattress-prototype on body temperatures and thermal comfort-an experimental study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 22, 43.
- ALLEN, R. 1990. *The Concise Oxford English Dictionary*. Oxford: Oxford University Press.
- ALMERUD, S., ALAPACK, R., FRIDLUND, B. & EKEBERGH, M. 2008. Caught in an artificial split: A phenomenological study of being a caregiver in the technologically intense environment. *Intensive and Critical Care Nursing*, 24, 130-136.
- AULICIEMS, A., SZOKOLAY, S. V., ORGANISATION, I. P. & ARCHITECTURE, U. O. Q. D. O. 1997. Thermal Comfort. PLEA notes.
- BARNARD, A. G. & SINCLAIR, M. 2006. Spectators & spectacles: Nurses, midwives and visibility. *Journal of Advanced Nursing*, 55, 578-586.
- BORGLIN, G. & RICHARDS, D. A. 2010. Bias in experimental nursing research: strategies to improve the quality and explanatory power of nursing science. *International Journal of Nursing Studies*, 47, 123-128.
- BROWN, C. 1999. Maintaining intraoperative normothermia: a meta-analysis of outcomes with costs. *American Association of Nurse Anesthetists*, 67, 155.
- BUJDOSO, P. J. 2009. Blanket warming: comfort and safety. *Association of periOperative Registered Nurses Journal*, 89, 717-722.
- BURGER, L. & FITZPATRICK, J. 2009. Prevention of inadvertent perioperative hypothermia. *British Journal of Nursing*, 18, 1114-1119.
- CANDAS, V. & DUFOUR, A. 2007. Hand skin temperatures associated with local hand discomfort under whole-body cold exposure. *Journal of the Human-Environmental System*, 10, 31-37.
- CASSAR, M. R. & CAMILLERI, A. S. 2014. A study of hypothermic patients presenting to a Mediterranean emergency department. *European Journal of Emergency Medicine*, 22, 35-41.
- COLLINS, K., EXTON-SMITH, A., JAMES, M. & OLIVER, D. 1980. Functional changes in autonomic nervous responses with ageing. *Age and ageing*, 9, 17-24.
- CORNELI, H. M. 2012. Accidental Hypothermia. *Pediatric Emergency Care*, 28, 475.
- DANZL, D. F. & POZOS, R. S. 1994. Accidental hypothermia. *New England Journal of Medicine*, 331, 1756-1760.

- DOUFAS, A. G. 2003. Consequences of inadvertent perioperative hypothermia. *Best Practice & Research Clinical Anaesthesiology*, 17, 535-549.
- ELMQVIST, C., FRIDLUND, B. & EKEBERGH, M. 2008. More than medical treatment: The patient's first encounter with prehospital emergency care. *International Emergency Nursing*, 16, 185-192.
- ENGELEN, S., HIMPE, D., BORMS, S., BERGHMANS, J., VAN CAUWELAERT, P., DALTON, J. & SESSLER, D. 2011. An evaluation of underbody forced-air and resistive heating during hypothermic, on-pump cardiac surgery. *Anaesthesia*, 66, 104-110.
- ERIKSSON, K. 1994. *Den lidande människan (The suffering human being) (in Swedish)*, Stockholm, Liber utbildning.
- FANGER, P. 1973. Assessment of man's thermal comfort in practice. *British Journal of Industrial Medicine*, 30, 313-324.
- FARLEY, A. & MCLAFFERTY, E. 2008. Nursing management of the patient with hypothermia. *Nursing Standard*, 22, 43-6.
- FRANK, S. M. 2000. Pathophysiology and consequences of hypothermia. *Anesthesiology*, 93, 611-8.
- GAGGE, A. P., STOLWIJK, J. A. & HARDY, J. D. 1967. Comfort and thermal sensations and associated physiological responses at various ambient temperatures. *Environmental Research*, 1, 1-20.
- GENG, Q., HOLMER, I., DEN EA, H., HAVENITH, G., JAY, O., MALCHAIRE, J., PIETTE, A., RINTAMÄKI, H. & RISSANEN, S. 2006. Temperature limit values for touching cold surfaces with the fingertip. *Annals of Occupational Hygiene*, 50, 851-862.
- GIESBRECHT, G. G. 2000. Cold stress, near drowning and accidental hypothermia: a review. *Aviation, Space, and Environmental Medicine*, 71, 733-752.
- GIESBRECHT, G. G. 2001. Emergency treatment of hypothermia. *Emergency Medicine*, 13, 9-16.
- GIESBRECHT, G. G., SESSLER, D. I., MEKJAVIC, I. B., SCHROEDER, M. & BRISTOW, G. K. 1994. Treatment of mild immersion hypothermia by direct body-to-body contact. *Journal of Applied Physiology*, 76, 2373-2379.
- GIESBRECHT, G. G. & WILKERSON, J. A. 2006. Hypothermia, frostbite, and other cold injuries: prevention, survival, rescue and treatment. Seattle: The Mountaineers Books.
- GRANEHEIM, U. H. & LUNDMAN, B. 2004. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today*, 24, 105-12.
- GREIF, R., RAJEK, A., LACINY, S. & SESSLER, D. I. 2000. Resistive heating is more effective than metallic-foil insulation in an experimental model of accidental hypothermia: a randomized controlled trial. *Annals of Emergency Medicine*, 35, 337-345.
- GRIMM, A., HULSE, L., PREISS, M. & SCHMIDT, S. 2014. Behavioural, emotional, and cognitive responses in European disasters: results of survivor interviews. *Disasters*, 38, 62-83.

- GROL, R., WENSING, M., ECCLES, M. & DAVIS, D. 2013. *Improving Patient Care: The Implementation of Change in Health Care*, West Succex, United Kingdom, John Wiley & Sons.
- HALLBERG, I. R. 2006. Challenges for future nursing research: providing evidence for health-care practice. *International Journal of Nursing Studies*, 43, 923-927.
- HASPER, D., NEE, J., SCHEFOLD, J., KRUEGER, A. & STORM, C. 2011. Tympanic temperature during therapeutic hypothermia. *Emergency Medicine Journal*, 28, 483-485.
- HELM, M., LAMPL, L., HAUKE, J. & BOCK, K. 1995. Accidental hypothermia in trauma patients. Is it relevant to preclinical emergency treatment? *Anaesthetist*, 44, 101.
- HENDERSON, V. & SILFVENIUS, U.-B. 1982. *Grundprinciper för patientvårdande verksamhet (Basic principles of nursing care) (in Swedish)*, Stockholm, LiberYrkesutbildning
- HENRIKSSON, O., LUNDGREN, J. P., KUKLANE, K., HOLMÉR, I. & BJORNSTIG, U. 2009. Protection against cold in prehospital care—thermal insulation properties of blankets and rescue bags in different wind conditions. *Prehospital and Disaster Medicine*, 24, 408-415.
- HENRIKSSON, O., LUNDGREN, P., KUKLANE, K., HOLMÉR, I., NAREDI, P. & BJORNSTIG, U. 2012. Protection against cold in prehospital care: evaporative heat loss reduction by wet clothing removal or the addition of a vapor barrier—a thermal manikin study. *Prehospital and Disaster Medicine*, 27, 53-58.
- HENSEL, H. 1981. *Thermoreception and temperature regulation*, London, Academic press.
- HENSEN, J. L. M. 1991. *On the thermal interaction of building structure and heating and ventilating system*. Dissertations Technische Universiteit
- HOLMÉR, I. 2004. Cold but comfortable? Application of comfort criteria to cold environments. *Indoor Air*, 14, 27-31.
- HOLMÉR, I., HASSI, J., IKÄHEIMO, T. M. & JAAKKOLA, J. J. 2012. Cold Stress: Effects on Performance and Health. *Patty's Toxicology*. 6 ed.: John Wiley & Sons.
- HOOPER, V. D., CHARD, R., CLIFFORD, T., FETZER, S., FOSSUM, S., GODDEN, B., MARTINEZ, E. A., NOBLE, K. A., O'BRIEN, D. & ODOM-FORREN, J. 2010. ASPAN's evidence-based clinical practice guideline for the promotion of perioperative normothermia. *Journal of PeriAnesthesia Nursing*, 25, 346-365.
- HULTZER, M. V., XU, X., MARRAO, C., BRISTOW, G., CHOCHINOV, A. & GIESBRECHT, G. G. 2005. Pre-hospital torso-warming modalities for severe hypothermia: a comparative study using a human model. *Canadian Journal of Emergency Medicine*, 7, 378-86.
- KALLENBERG, K. & LARSSON, G. 2000. *Människans hälsa. Livsåskådning och personlighet (in Swedish) (Human being's health. Philosophy of life and personality)*, Stockholm, Natur och Kultur.
- KARLSEN, A. M., THOMASSEN, O., VIKENES, B. H. & BRATTEBØ, G. 2013. Equipment to prevent, diagnose, and treat hypothermia: a

- survey of Norwegian pre-hospital services. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 21, 63.
- KEIM, S. M., GUISTO, J. A. & SULLIVAN, J. B., JR. 2002. Environmental thermal stress. *Annals of Agricultural and Environmental Medicine*, 9, 1-15.
- KELLEY, K. & PREACHER, K. J. 2012. On effect size. *Psychological Methods*, 17, 137.
- KINGMA, B., FRIJNS, A. & VAN MARKEN LICHTENBELT, W. 2012. The thermoneutral zone: implications for metabolic studies. *Frontiers in Bioscience*, 4, 1975.
- KOBER, A., DOBROVITS, M., DJAVAN, B., MARBERGER, M., BARKER, R., BERTALANFFY, P., SCHECK, T., GUSTORFF, B. & HOERAUF, K. 2003. Local active warming: an effective treatment for pain, anxiety and nausea caused by renal colic. *Journal of Urology*, 170, 741-4.
- KOBER, A., SCHECK, T., FULESDI, B., LIEBA, F., VLACH, W., FRIEDMAN, A. & SESSLER, D. I. 2001. Effectiveness of resistive heating compared with passive warming in treating hypothermia associated with minor trauma: a randomized trial. *Mayo Clinical Proceedings*, 76, 369-75.
- KOBER, A., SCHECK, T., LIEBA, F., BARKER, R., VLACH, W., SCHRAMM, W. & HOERAUF, K. 2002. The influence of active warming on signal quality of pulse oximetry in prehospital trauma care. *Anesthesia & Analgesia*, 95, 961-6.
- KOLCABA, K. & WILSON, L. 2002. Comfort care: A framework for perianesthesia nursing. *Journal of PeriAnesthesia Nursing*, 17, 102-114.
- KOLCABA, K. Y. 1991. A taxonomic structure for the concept comfort. *Journal of Nursing Scholarship*, 23, 237-240.
- KOLCABA, K. Y. 1994. A theory of holistic comfort for nursing. *Journal of Advanced Nursing*, 19, 1178-1184.
- KOLCABA, K. Y. & FISHER, E. M. 1996. A holistic perspective on comfort care as an advance directive. *Critical Care Nursing Quarterly*, 18, 66-76.
- KOLCABA, K. Y. & KOLCABA, R. J. 1991. An analysis of the concept of comfort. *Journal of Advanced Nursing*, 16, 1301-1310.
- KRIPPENDORFF, K. 2012. *Content analysis: An introduction to its methodology*, University of Pennsylvania, Sage.
- KURZ, A., SESSLER, D. I., BIRNBAUER, F., ILLIEVICH, U. M. & SPISS, C. K. 1995. Thermoregulatory vasoconstriction impairs active core cooling. *Anesthesiology*, 82, 870.
- KURZ, A., SESSLER, D. I. & LENHARDT, R. 1996. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. *New England Journal of Medicine*, 334, 1209-1216.
- LANGHELLE, A., LOCKEY, D., HARRIS, T. & DAVIES, G. 2012. Body temperature of trauma patients on admission to hospital: a comparison of anaesthetised and non-anaesthetised patients. *Emergency Medicine Journal*, 29, 239-242.

- LEETH, D., MAMARIL, M., OMAN, K. S. & KRUMBACH, B. 2010. Normothermia and patient comfort: a comparative study in an outpatient surgery setting. *Journal of PeriAnesthesia Nursing*, 25, 146-151.
- LEVINE, M. E. 1967. The four conservation principles of nursing. *Nursing Forum*, 6, 45-59.
- LEVINE, M. E. 1991. *The conservation principles: a model for health*, Philadelphia, FA Davis.
- LIEM, S. T. & ALDRETE, J. A. 1974. Control of post-anaesthetic shivering. *Canadian Anaesthesiologists' Society Journal*, 21, 506-10.
- LIM, C. & DUFLOU, J. 2008. Hypothermia fatalities in a temperate climate: Sydney, Australia. *Pathology*, 40, 46-51.
- LINTU, N. S., MATTILA, M. A. K., HOLOPAINEN, J. A., KOIVUNEN, M. & HÄNINEN, O. O. P. 2006. Reactions to cold exposure emphasize the need for weather protection in prehospital care: an experimental study. *Prehospital and Disaster Medicine*, 21, 316-321.
- LUNDGREN, J. P., HENRIKSSON, O., PRETORIUS, T., CAHILL, F., BRISTOW, G., CHOCHINOV, A., PRETORIUS, A., BJORNSTIG, U. & GIESBRECHT, G. G. 2009. Field torso-warming modalities: a comparative study using a human model. *Prehospital Emergency Care*, 13, 371-8.
- LUNDGREN, P., HENRIKSSON, O., KUKLANE, K., HOLMÉR, I., NAREDI, P. & BJÖRNSTIG, U. 2013. Validity and reliability of the Cold Discomfort Scale: a subjective judgement scale for the assessment of patient thermal state in a cold environment. *Journal of Clinical Monitoring and Computing*, 28, 287-291.
- LUNDGREN, P., HENRIKSSON, O., NAREDI, P. & BJORNSTIG, U. 2011. The effect of active warming in prehospital trauma care during road and air ambulance transportation - a clinical randomized trial. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 19, 59.
- LYON, D. 2003. Surveillance technology and surveillance society. *Modernity and Technology*, 161-83.
- MARION, G., MCGANN, K. P. & CAMP, D. L. 1991. Core body temperature in the elderly and factors which influence its measurement. *Gerontology*, 37, 225-232.
- MASLOW, A. H. 1943. A theory of human motivation. *Psychological Review*, 50, 370-396.
- MASLOW, A. H., FRAGER, R., FADIMAN, J., MCREYNOLDS, C. & COX, R. 1970. *Motivation and personality*, Harper & Row New York.
- MCGLYNN, E. A., ASCH, S. M., ADAMS, J., KEESEY, J., HICKS, J., DECRISTOFARO, A. & KERR, E. A. 2003. The quality of health care delivered to adults in the United States. *New England Journal of Medicine*, 348, 2635-2645.
- MCILVEEN, K. H. & MORSE, J. M. 1995. The role of comfort in nursing care: 1900-1980. *Clinical Nursing Research*, 4, 127-148.
- MELLING, A. C., ALI, B., SCOTT, E. M. & LEAPER, D. J. 2001. Effects of preoperative warming on the incidence of wound infection after

- clean surgery: a randomised controlled trial. *The Lancet*, 358, 876-880.
- MERILÄINEN, M., KYNGÄS, H. & ALA-KOKKO, T. 2010. 24-hour intensive care: an observational study of an environment and events. *Intensive and Critical Care Nursing*, 26, 246-253.
- MISHLER, E. G. 2005. Patient stories, narratives of resistance and the ethics of humane care: a la recherche du temps perdu. *Health (London)*, 9, 431-51.
- MORITZ, A. 1947. Studies of thermal injury: III. the pathology and pathogenesis of cutaneous burns. an experimental study. *The American Journal of Pathology*, 23, 915.
- MORRISON, R. C. 1988. Hypothermia in the elderly. *International Anesthesiology Clinics*, 26, 124-133.
- MORSE, J. M. 1997. Responding to threats to integrity of self. *Advances in Nursing Science*, 19, 21-36.
- MORSE, J. M. & FIELD, P.-A. 1996. *Nursing research: The application of qualitative approaches*, Cheltenham. United Kingdom, Nelson Thornes.
- NEUMAN, B. M. & FAWCETT, J. 1989. *The Neuman systems model*, Norwalk, Appleton & Lange
- NGUYEN, H.-H., CHIARI, A. & KIMBERGER, O. 2010. A New Underbody Resistive Warming Device vs. Forced Air Warming To Prevent Perioperative Hypothermia. *Annual Meeting of the American Society Anesthesiologists*.
- NIGHTINGALE, F. 1863. *Notes on Hospitals*, London, Longman, Green, Longman, Roberts, and Green.
- NUHR, M., HOERAUF, K., BERTALANFFY, A., BERTALANFFY, P., FRICKEY, N., GORE, C., GUSTORFF, B. & KOBER, A. 2004. Active warming during emergency transport relieves acute low back pain. *Spine*, 29, 1499.
- OLOFSSON, B., STENVALL, M., LUNDSTRÖM, M., SVENSSON, O. & GUSTAFSON, Y. 2007. Malnutrition in hip fracture patients: an intervention study. *Journal of Clinical Nursing*, 16, 2027-2038.
- PALMIERE, C., TERESIŃSKI, G. & HEJNA, P. 2014. Postmortem diagnosis of hypothermia. *International Journal of Legal Medicine*, 1-8.
- PARSONS, K. 2014. *Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort and performance*, Boca Raton, Crc Press.
- PATERSON, J. G. & ZDERAD, L. T. 1988. *Humanistic nursing*. New York: The Project Gutenberg.
- PELLERIN, N., DESCHUYTENEER, A. & CANDAS, V. 2004. Local thermal unpleasantness and discomfort prediction in the vicinity of thermoneutrality. *European Journal of Applied Physiology*, 92, 717-20.
- PENG, R. Y. & BONGARD, F. S. 1999. Hypothermia in trauma patients. *Journal of the American College of Surgeons*, 188, 685.
- PETRONE, P., KUNCIR, E. J. & ASENSIO, J. A. 2003. Surgical management and strategies in the treatment of hypothermia and cold injury. *Emergency Medicine Clinics of North America*, 21.

- PLUYE, P., GAGNON, M.-P., GRIFFITHS, F. & JOHNSON-LAFLEUR, J. 2009. A scoring system for appraising mixed methods research, and concomitantly appraising qualitative, quantitative and mixed methods primary studies in Mixed Studies Reviews. *International Journal of Nursing Studies*, 46, 529-546.
- POLIT, D. F. & BECK, C. T. 2010. Generalization in quantitative and qualitative research: Myths and strategies. *International Journal of Nursing Studies*, 47, 1451-1458.
- POLIT, D. F. & BECK, C. T. 2013. *Essentials of nursing research: Appraising evidence for nursing practice*, Philadelphia, Lippincott Williams & Wilkins.
- PU, Y., CEN, G., SUN, J., GONG, J., ZHANG, Y., ZHANG, M., WU, X., ZHANG, J., QIU, Z. & FANG, F. 2014. Warming with an underbody warming system reduces intraoperative hypothermia in patients undergoing laparoscopic gastrointestinal surgery: A randomized controlled study. *International Journal of Nursing Studies*, 51, 181-189.
- RAJAGOPALAN, S., MASCHA, E., NA, J. & SESSLER, D. I. 2008. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. *Anesthesiology*, 108, 71-77.
- RICHARDS, D. A. & HAMERS, J. P. 2009. RCTs in complex nursing interventions and laboratory experimental studies. *International Journal of Nursing Studies*, 46, 588-592.
- ROBINSON, S. & BENTON, G. 2002. Warmed blankets: an intervention to promote comfort for elderly hospitalized patients. *Geriatric Nursing*, 23, 320-3.
- ROTELLO, L. C., CRAWFORD, L. & TERNDRUP, T. E. 1996. Comparison of infrared ear thermometer derived and equilibrated rectal temperatures in estimating pulmonary artery temperatures. *Critical Care Medicine*, 24, 1501.
- SANDELOWSKI, M. 1991. Telling stories: Narrative approaches in qualitative research. *Image: the Journal of Nursing Scholarship*, 23, 161-166.
- SANDELOWSKI, M. 2000. Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies. *Research in Nursing & Health*, 23, 246-255.
- SCHLADER, Z. J., PRANGE, H. D., MICKLEBOROUGH, T. D. & STAGER, J. M. 2009. Characteristics of the control of human thermoregulatory behavior. *Physiology & Behavior*, 98, 557-62.
- SCHLADER, Z. J., STANNARD, S. R. & MÜNDEL, T. 2010. Human thermoregulatory behavior during rest and exercise--A prospective review. *Physiology & Behavior*, 99, 269-275.
- SESSLER, D. I. 1997. Mild perioperative hypothermia. *New England Journal of Medicine*, 336, 1730-1737.
- SESSLER, D. I. 2001. Complications and treatment of mild hypothermia. *Anesthesiology*, 95, 531-543.
- SESSLER, D. I. & SCHROEDER, M. 1993. Heat loss in humans covered with cotton hospital blankets. *Anesthesia & Analgesia*, 77, 73-77.

- SHADISH, W. R., COOK, T. D. & CAMPBELL, D. T. 2002. *Experimental and quasi-experimental designs for generalized causal inference*, Boston, Wadsworth Cengage learning.
- SITZMAN, K. & EICHELBERGER, L. W. 2010. *Understanding the work of nurse theorists: A creative beginning*, Sudbury, Jones & Bartlett Publishers.
- SPIELBERGER, C. D. & SYCLEMAN, S. J. 1994. State-Trait Anxiety Inventay and State-Trait Anger Expression Inventory. *The Use Of Psychological Testing For Treatment Planning and Outcome Assessment*. Third ed. Maruish, E Mark.
- SRAN, B. J. K., MCDONALD, G. K., STEINMAN, A. M., GARDINER, P. F. & GIESBRECHT, G. G. 2014. Comparison of heat donation through the head or torso on mild hypothermia rewarming. *Wilderness & Environmental Medicine*.
- STATISTICS SWEDEN 2013. Cold and warm days, and days with precipitation across Sweden. *Statistical Yearbook of Sweden 2013*. Örebro: Statistics Sweden.
- STOCKS, J. M., TAYLOR, N. A., TIPTON, M. J. & GREENLEAF, J. E. 2004. Human physiological responses to cold exposure. *Aviation, Space, and Environmental Medicine* 75, 444-57.
- SUND-LEVANDER, M., GRODZINSKY, E., LOYD, D. & WAHREN, L. K. 2004. Errors in body temperature assessment related to individual variation, measuring technique and equipment. *International Journal of Nursing Practice*, 10, 216-223.
- THE NATIONAL BOARD OF HEALTH AND WELFARE 2002. *Hypothermia-Cold Injuries and Cold Water Near Drowning*, Stockholm, The National Board of Healt and Welfare.
- THE WORLD MEDICAL ASSOCIATION. 2008. *Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects* [Online]. <http://www.wma.net/en/30publications/10policies/b3/>.
- THOMASSEN, Ø., FÆREVIK, H., ØSTERÅS, Ø., SUNDE, G. A., ZAKARIASSEN, E., SANDSUND, M., HELTNE, J. K. & BRATTEBØ, G. 2011. Comparison of three different prehospital wrapping methods for preventing hypothermia-a crossover study in humans. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 19, 41.
- TSUEI, B. J. & KEARNEY, P. A. 2004. Hypothermia in the trauma patient. *Injury*, 35, 7-15.
- WAGNER, D., BYRNE, M. & KOLCABA, K. 2006. Effects of Comfort Warming on Preoperative Patients. *Association of periOperative Registered Nurses*, 84, 427-448.
- WAGNER, J. A. & HORVATH, S. M. 1985. Cardiovascular reactions to cold exposures differ with age and gender. *Journal of Applied Physiology*, 58, 187-192.
- VALERI, C. R., MACGREGOR, H., CASSIDY, G., TINNEY, R. & POMPEI, F. 1995. Effects of temperature on bleeding time and clotting time in normal male and female volunteers. *Critical Care Medicine*, 23, 698-704.

- VAN MARKEN LICHTENBELT, W. D., SCHRAUWEN, P., VAN DE KERCKHOVE, S. & WESTERTERP-PLANTENGA, M. S. 2002. Individual variation in body temperature and energy expenditure in response to mild cold. *American Journal of Physiology-Endocrinology and Metabolism*, 282, E1077-E1083.
- WANG, D., ZHANG, H., ARENS, E. & HUIZENGA, C. 2007. Observations of upper-extremity skin temperature and corresponding overall-body thermal sensations and comfort. *Building and Environment*, 42, 3933-3943.
- WATTS, D. D., ROCHE, M., TRICARICO, R., POOLE, F., BROWN, J. J., COLSON, G. B., TRASK, A. L. & FAKHRY, S. M. 1999. The utility of traditional prehospital interventions in maintaining thermostasis. *Prehospital Emergency Care*, 3, 115-122.
- VERHEYEN, J., THEYS, N., ALLONSIUS, L. & DESCAMPS, F. 2011. Thermal comfort of patients: Objective and subjective measurements in patient rooms of a Belgian healthcare facility. *Building and Environment*, 46, 1195-1204.
- WHO 2005. Bridging the "know-do" gap: Meeting on Knowledge Translation in Global Health. Retrieved September, 25, 2006.
- WIKLUND, L. 2003. Vårdvetenskap i klinisk praxis (in Swedish).
- WILLIAMS, A., SALMON, A., GRAHAM, P., GALLER, D., PAYTON, M. & BRADLEY, M. 2005. Rewarming of healthy volunteers after induced mild hypothermia: a healthy volunteer study. *Emergency Medicine Journal*, 22, 182-184.
- WIREKLINT SUNDSTRÖM, B. & DAHLBERG, K. 2011. Caring assessment in the Swedish ambulance services relieves suffering and enables safe decisions. *International Emergency Nursing*, 19, 113-119.
- VOGELSANG, J. 1994. Patients talk about their postanesthesia shaking experiences. *Journal of Post Anesthesia Nursing*, 9, 214-218.
- WONG, P., KUMAR, S., BOHRA, A., WHETTER, D. & LEAPER, D. 2007. Randomized clinical trial of perioperative systemic warming in major elective abdominal surgery. *British Journal of Surgery*, 94, 421-426.
- WRANGHAM, R. 2009. *Catching fire: how cooking made us human*, New York, Basic Books.
- ZHANG, H., HUIZENGA, C., ARENS, E. & WANG, D. 2004. Thermal sensation and comfort in transient non-uniform thermal environments. *European Journal of Applied Physiology* 92, 728-33.