

Review article

The prehospital management of hypothermia – An up-to-date overview[☆]



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ABSTRACT

Background: Accidental hypothermia concerns a body core temperature of less than 35 °C without a primary defect in the thermoregulatory system. It is a serious threat to prehospital patients and especially injured patients, since it can induce a vicious cycle of the synergistic effects of hypothermia, acidosis and coagulopathy; referred to as the trauma triad of death. To prevent or manage deterioration of a cold patient, treatment of hypothermia should ideally begin prehospital. Little effort has been made to integrate existent literature about prehospital temperature management. The aim of this study is to provide an up-to-date systematic overview of the currently available treatment modalities and their effectiveness for prehospital hypothermia management.

Data sources: Databases PubMed, EMBASE and MEDLINE were searched using the terms: “hypothermia”, “accidental hypothermia”, “Emergency Medical Services” and “prehospital”. Articles with publications dates up to October 2017 were included and selected by the authors based on relevance.

Results: The literature search produced 903 articles, out of which 51 focused on passive insulation and/or active heating. The most effective insulation systems combined insulation with a vapor barrier. Active external rewarming interventions include chemical, electrical and charcoal-burning heat packs; chemical or electrical heated blankets; and forced air warming. Mildly hypothermic patients, with significant endogenous heat production from shivering, will likely be able to rewarm themselves with only insulation and a vapor barrier, although active warming will still provide comfort and an energy-saving benefit. For colder, non-shivering patients, the addition of active warming is indicated as a non-shivering patient will not rewarm spontaneously. All intravenous fluids must be reliably warmed before infusion.

Conclusion: Although it is now accepted that prehospital warming is safe and advantageous, especially for a non-shivering hypothermic patient, this review reveals that no insulation/heating combinations stand significantly above all the others. However, modern designs of hypothermia wraps have shown promise and battery-powered inline fluid warmers are practical devices to warm intravenous fluids prior to infusion. Future research in this field is necessary to assess the effectiveness expressed in patient outcomes.

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Introduction

Accidental hypothermia is defined as an unintentional decrease in body temperature to below 35°C, without the presence of a primary defect in the patient's thermoregulatory mechanism. It can be subdivided into mild (35–32°C), moderate (32–28°C) and severe (<28°C) hypothermia; a temperature below which cardiac arrest or low flow state can occur [1]. Hypothermia negatively affects multiple organ systems [2–6], and is associated with poor outcomes including death [7–13]. In the United States, approximately 1500 people die of primary hypothermia each year [14]. The etiology of hypothermia is multifactorial and the assumed main causes of accidental hypothermia in injured patients are heat loss due to environmental exposure, the administration of cold intravenous fluids, hemorrhagic shock and the effects of anesthesia or sedation on thermoregulation [15–17].

All prehospital patients could become hypothermic due to their sickness or injury. Especially in the severely injured trauma patients its incidence ranges from 13.3% to 43% in various prehospital environments worldwide [11,13,18–20]. In studies of trauma patients who were hypothermic on arrival at the emergency department, the average core temperature was 33.5°C [13,18,19,21,22]. Hypothermia is one of the components of the trauma triad of death, which is a vicious cycle caused by the synergistic effects that hypothermia, coagulopathy and acidosis have on each other [18,25–27].

One of the effects of hypothermia is poor tissue oxygenation throughout the body caused by peripheral vasoconstriction, decreased myocardial contractility and decreased oxygen release from hemoglobin to tissue [16,23–25]. This effect on tissue oxygenation causes an increase in the cell metabolism's proportion of anaerobic metabolism. Normally, during aerobic metabolism, heat is produced by the hydrolysis of adenosine triphosphate (ATP)

to adenosine diphosphate (ADP); in contrast, the anaerobic metabolism results in decreased ATP synthesis and consequently decreased heat production. Anaerobic metabolism also produces higher lactate levels and causes metabolic acidosis [24].

The activity of coagulation enzymes decreases with acidosis [15] and lower body temperatures. In addition, hypothermia causes a defect in the aggregation and adhesion of platelets and a decrease of fibrinogen availability, resulting in prolonged bleeding times [26,27]. These abnormalities can be reversed by rewarming [26].

Early recognition and treatment of hypothermia is essential to oppose the deterioration of a patient's condition. Treatment ideally begins in the prehospital setting and should focus on reducing heat loss, promoting cardiovascular stability, restoring fluid volumes and reversing core cooling. Regarding core temperature maintenance, there is considerable laboratory-based literature specifically regarding properties of insulation materials and heat sources, as well as randomized controlled trials on rewarming methods for cold subjects, but little effort has been made to integrate all of this information. The most recent reviews, which focused primarily on the prehospital treatment of hypothermia, were performed 16 years ago [28,29]. As well, there is a shortage of large randomized controlled trials conducted in the pre-hospital setting.

The aim of this review article is to provide an up-to-date systematic overview of the available treatment modalities relating to insulation and/or application of heat for the prehospital management of hypothermic patients and to present the best available evidence for their effectiveness to improve patient care.

Methods

The databases PubMed, EMBASE (OvidSP) and MEDLINE (OvidSP) were searched using various keywords and strategies;

Table 1
Literature search.

	EMbase (OvidSP)	MEDLINE (OvidSP)	PubMed
Search strategy	1. exp accidental hypothermia/or exp hypothermia/or hypothermia.mp. 2. hypothermia.af. 3. hypotherm* 4. prehospital.af. 5. 1 or 2 or 3 6. 4 and 5 7. limit 6 to (exclude medline journals and (dutch or english))	1. hypothermia.mp. or exp Hypothermia/ 2. hypothermia.af. 3. hypotherm* 4. prehospital.af. 5. exp Emergency Medical Services/or prehospital.mp. 6. 1 or 2 or 3 7. 4 or 5 8. 6 and 7 9. limit 8 to (dutch or english)	((("hypothermia"[All Fields]) OR (hypotherm*)) AND prehospital[All Fields]) AND (English[lang] OR Dutch[lang])
Hits	32	948	288

Conducted during October 2017.

which are listed in Table 1. Articles with publication dates up to October 2017 were reviewed. The relevance of the articles was judged by their title; abstract and full-text; which were all screened by two authors (FH; ET) and discussed with the third author (GG). Articles were included if they contained information about treatment modalities for hypothermia that could be applied prehospital. There were no exclusion criteria and studies published in any year were taken into consideration. Patient population includes prehospital hypothermic patients or experimental subjects. The references of the included studies were screened to identify if they contained other relevant articles. Furthermore; the level of evidence was determined for the articles that contained information about the effectiveness of a treatment modality; these levels are listed in Tables 3–5. The assessment of the evidence was completed according to The Levels of Evidence 2 Table of the Oxford Centre for Evidence-based Medicine [30]. After collection of the data; we contacted manufacturers to gain more information about the specifications of the discussed products. In our overview; we describe the characteristics of the available treatment modalities and summarize the existing scientific data per intervention.

Results

The literature search returned 903 potential inclusions for consideration, of which 51 focused on insulation only (with or without a vapor barrier) (to decrease heat loss) and/or active heating (Fig. 1). An overview of these studies is displayed in Table 2.

The interventions are categorized into insulation/vapor barrier materials, external heat sources and heat sources with internal heat transfer. The term ‘hypothermia wrap’ refers to insulation with or without vapor barrier and a heat source.

Insulation/vapor barrier materials

The treatment of a hypothermic patient starts with extracting the patient from the cold setting and any dangerous conditions, removing wet clothes (once the patient can be protected from the cold environment), drying, insulating and providing a vapor barrier for the patient. To accomplish rewarming when only insulation is provided, the patient's thermoregulatory mechanisms and endocrine functions must be intact and they should have a body core temperature of over 32 °C and adequate energy stores to create endogenous heat through shivering heat production [31]. Shivering during mild hypothermia can increase heat production by three to five times the resting values [32]. Therefore, in severely hypothermic patients who are not shivering and have a greatly reduced metabolic rate, the main function of these wrapping methods is the reduction of heat loss rather than rewarming. Various covers are designed for the insulation of a patient and an overview of these, together with the best available evidence, is provided in Table 3.

The group of ultrathin plastic or foil covers which include the Akla Metallic Foil blanket (Akla AB, Sweden) and the Mediwrap Metallic Foil Blanket (Mediwrap Ltd, UK), has the lowest insulation value because these covers are so thin [33]. Thicker wool, cotton

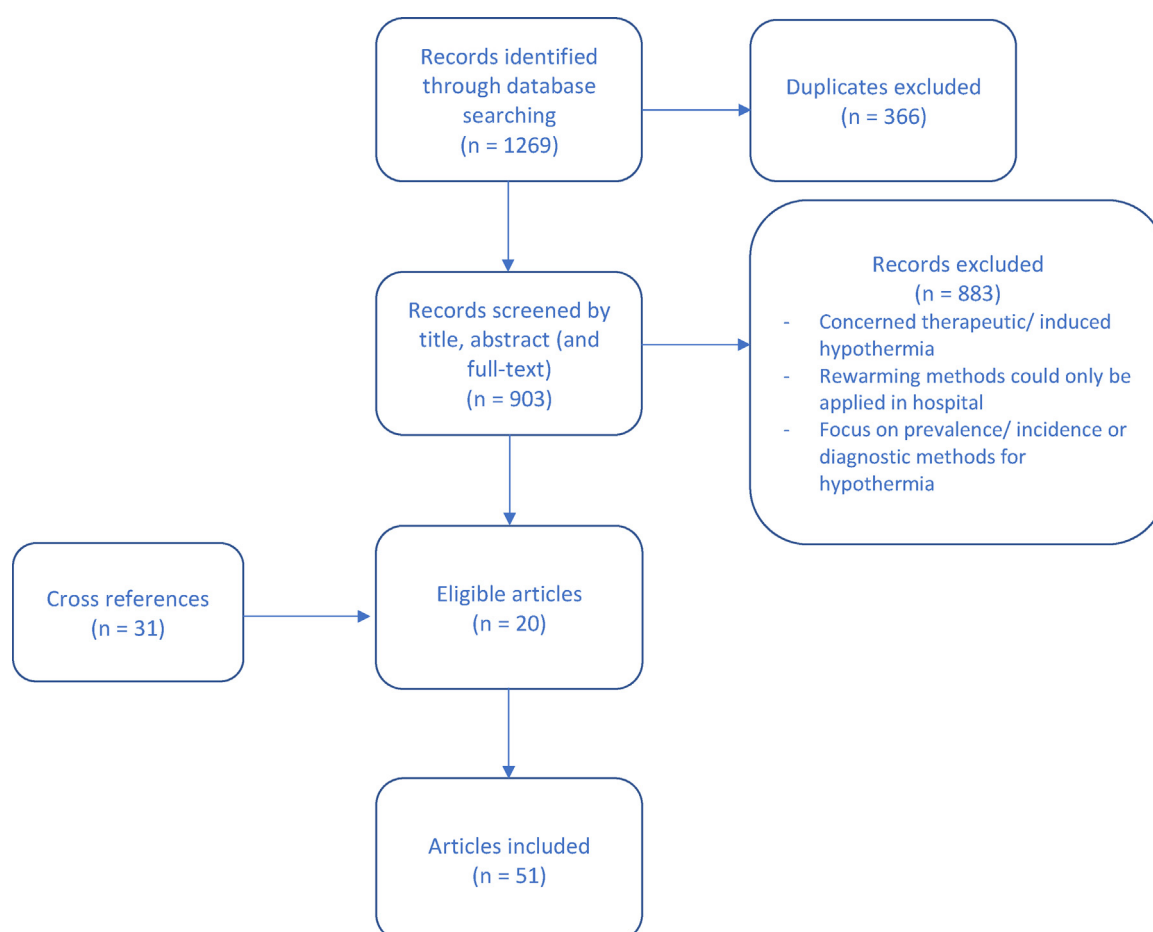


Fig. 1. Flowchart of the literature search.

Table 2
Overview of included studies.

Reference	Study type	Number of subjects	Treatment modalities for hypothermia	Outcome measures	Conclusion
[40]	Randomized controlled crossover experiment	N = 6	Shivering; charcoal-burning HeatPac; treadmill exercise	Esophageal temperature	Total recovery time did not differ among the three treatments
[66]	Randomized controlled crossover experiment	N = 8	Thermal Recovery Capsule (model LGS-TRC-A, Lifeguard Systems, Inc, Hurley, New York); Heat Pac Rescue Bag; inhalational warming; charcoal-burning HeatPac	Esophageal temperature; rectal temperature	Inhalation rewarming and peripheral rewarming are not recommended for the prehospital treatment of mild hypothermia
[41]	Controlled crossover experiment	N = 6	Shivering; body-to-body rewarming; rewarming with a constant-heat source manikin	Esophageal temperature; skin temperature; cutaneous heat flux; oxygen consumption	The rewarming rates during heat donation are not greater than during shivering
[59]	Randomized controlled crossover experiment	N = 8	Shivering inside a sleeping bag; forced-air warming	Esophageal temperature; skin temperature; cutaneous heat flux; metabolism	Forced air warming is a safe, simple, noninvasive treatment
[65]	Review	NA	NA; effects of a cold environment on the respiratory system were described	NA	Describes responses of the respiratory system to cold
[49]	Randomized controlled trial	N = 12	Shivering; charcoal-burning HeatPac; treadmill exercise (whether differences between efficacies are affected by body composition)	Esophageal temperature	The inter-treatment differences are accentuated in high fat group
[67]	Randomized controlled crossover experiment	N = 8	Warmed humidified air	Rectal temperature	Rewarming rates observed with inhalation rewarming in laboratory studies may over-estimate the rates of rewarming in the field
[58]	Randomized controlled trial	Treatment group N = 9 Control group N = 7	Forced-air; cotton blankets	Tympanic temperature; rectal temperatures	Forced air accelerated the rate of rewarming without producing complications
[46]	Survey	N = 41	Chemical pads; sleeping bag; hot water bottle; warmed intravenous fluids; warmed oxygen or air; charcoal-burning HeatPac; sarong	NA	Chemical heating pads are most commonly used for rewarming
[56]	Controlled crossover experiment	N = 8	Endogenous rewarming; inhalation rewarming; forced-air warming	Esophageal temperature; skin temperature; heat flux; oxygen consumption; heart rate; blood pressure	Forced-air warming provided a rewarming advantage, but inhalation rewarming did not
[63]	Randomized controlled crossover experiment	N = 5	Forced-air warming with soft cover; forced-air warming with rigid cover	Skin temperature; heat flux (loss)	Portable rigid covers are efficient for treatment of cold victims
[57]	Retrospective review	N = 15	Forced-air rewarming	Core (esophageal and tympanic) temperatures	Forced air warming is an efficient and safe warming method
[60]	Meta-analysis	Treatment group N = 728 Control group N = 847	Air blanket; forced-air warming (Bair Hugger); cotton blanket; space blanket; electric blanket; circulating water or alcohol; Warm Touch; humidified air	Postoperative temperatures	Intraoperative normothermia is maintained more effectively with forced air warming
[53]	Randomized controlled crossover experiment	N = 8	Reflective foil; carbon fibre-resistive heating blanket	Tympanic temperature; skin temperature	Resistive heating more than doubles the rewarming rate compared with reflective metal foil
[50]	Randomized controlled trial	Treatment group N = 50 Control group N = 50	Non-activated carbon-fibre resistive warming blanket and a wool blanket; activated carbon-fibre resistive warming blanket and a wool blanket	Tympanic temperature; oral temperatures; heart rate; pain; fear; overall satisfaction	Resistive heating augments thermal comforts, increases core temperature, reduces pain and anxiety, and improves overall patient satisfaction
[32]	Clinical trial	N = 15	NA; this trial concerns measurements of shivering intensity	Body temperature responses; metabolic responses (oxygen consumption); peak shivering response	The VO ₂ max, BMI, and age are significant variables in the prediction of the peak shivering metabolic rate
[28]	Review	NA	Ingestion of warm liquid; body-to-body contact; heating pads; inhalation of humidified air or oxygen; forced-air warming; resistive heating devices; warm water immersion of arms and legs; negative pressure warming; warm intravenous fluids	NA	Proposed algorithm for care of the hypothermic patient
[52]	Review	NA	Resistive heating; forced-air warming; warmed intravenous fluids	NA	Forced-air and resistive heating are currently the most effective noninvasive options for active warming. Intravenous fluids should be warmed when large volumes are required or

Table 2 (Continued)

Reference	Study type	Number of subjects	Treatment modalities for hypothermia	Outcome measures	Conclusion
[79]	Animal research	N = 6	Extracorporeal circulation	Rectal temperature	when forced air alone proves insufficient It is possible to bring a lightweight ECC system to the unstable patient; treatment is possible in any hospital, ambulance or helicopter
[43]	Position paper	NA	Humidified warm oxygen; passive insulation; heat packs; hot and sweet drinks	NA	Provides an algorithm for assessment and therapy
[39]	Randomized controlled trial	Treatment group N = 9 Control group N = 10	Insulated spine board (insulation: closed cell polyethylene, with thickness 15 mm)	Tympanic temperature; estimated sensation of cold; estimated level of shivering	Insulation on the spine board reduced the need for shivering
[31]	Review	NA	Hot water bottles; heating pads; forced-air warming; arteriovenous anastomoses/warm water immersion of hands or feet; humidified oxygen; warmed intravenous fluids	NA	Overview of pathophysiology, etiology, diagnosis, laboratory findings, management, rewarming, disposition and prevention
[48]	Randomized controlled crossover experiment	N = 6	Forced-air warming with a 600-W heater and commercial soft warming blanket; a 600-W heater and rigid cover; an 850-W heater and rigid cover; charcoal heater; body-to-body contact	Heat loss; endogenous heat production; exogenous heat delivery	External heat application was effective in attenuating core temperature afterdrop and facilitating safe core rewarming
[61]	Randomized controlled trials	Treatment group N = 20 Control group N = 20	Warm mattresses and cotton blankets; forced-air pre-warming before anesthesia	Core temperature; skin temperature; hemodynamic variables	Forced air warming before the induction of anesthesia reduced the incidence and degree of redistribution hypothermia
[51]	Animal research	N = 6 N = 7 N = 7	Chillbuster warming blanket; chillbuster plus reflective blanket; two wool blankets	Core (pulmonary artery) temperature; rectal temperature; skin temperature	A warm blanket plus reflective blanket was effective in preventing hypothermia
[33]	Laboratory study	NA	Rescue blankets; woolen blankets; plastic cover; polyester blanket; bubble wrap; metallic foil blanket	Clo [#]	Overview of insulation values in different wind conditions
[47]	Controlled crossover experiment	N = 5	Charcoal heater; hot water bags; chemical heat pads	Esophageal temperature; skin temperature; endogenous heat production; heart rate; respiratory rate; exogenous heat delivery of each rewarming method	Advice to use charcoal heaters, chemical heat pads or hot water bags
[64]	Retrospective review	N = 1364	HPMK; warmed intravenous fluids; forced-air warming; warmed blankets; wool blanket; reflective blanket; human remains pouch	Core temperature	No differences were found in the capability of maintaining temperatures between the different thermoregulatory methods
[35]	Laboratory study	NA	HPMK; Ready-Heat blanket; forced-air warming (Bair Hugger); woolen blanket; space blanket; Blizzard blanket; human remains pouch; Hot Pocket	Temperature of the thermal manikin	The original HPMK maintained the highest temperatures; in near room temperature, passive warming methods were as effective as active warming devices other than HPMK
[37]	Randomized controlled crossover experiment	N = 7	Bubble wrap; ambulance blankets/quilts; Hibler's method (combination of vapor tight layer and an additional dry insulating layer); combination of a plastic outer layer with an insulating layer	Skin temperature; rectal temperature; oxygen consumption; metabolic heat production; comfort; thermal sensation; shivering	The Hibler's method is the most efficient wrapping method to prevent heat loss
[71]	Calorimetric model	NA	Warmed intravenous fluids	Change in body temperature; volume required to warm patient; temperature required to rewarm patient	The main contribution of active fluid warming is prevention of further heat loss to the environment rather than true heating. It will remain an effective and critical tool, as long as it is judiciously used in tandem with other active heating modalities with full knowledge of its limitations
[45]	Survey	N = 42	Space blankets; hospital duvets; cotton blankets; plastic "bubble wrap"; wool blankets; sleeping bags; (insulated) shelter bags; separate head cover; body bags; plastic covers; chemical heat pads; water bottles; electrical heating blankets; forced air warmer; warmed intravenous fluids	NA	Most common equipment types are duvets, bubble wrap and cotton blankets
[62] [68]	Guidelines Retrospective review	NA NA	Forced-air warming NA; study aim is to determine factors associated with hypothermia	NA Axillary or rectal temperature	Provide basic recommendations HEMS trauma patients who have received blood are more likely to arrive hypothermic
[72]	Guidelines	NA	Insulation; heat packs; warmed humidified oxygen; warmed intravenous fluids	NA	Guideline and algorithm for management of avalanche victims
[73]	Review	NA		NA	

Table 2 (Continued)

Reference	Study type	Number of subjects	Treatment modalities for hypothermia	Outcome measures	Conclusion
			Drying patient; warm environment; shivering; blanket or clothing insulation; head cover; heating pads; warm water blankets; warm water bottles; immersion in warm bath; external convection heaters; heated intravenous fluids; body cavity lavage; warmed inhalational agents; extracorporeal rewarming		Review of the normal thermoregulation, mechanisms of heat loss, systematic effects of hypothermia, specific cold injuries and their treatment
[42]	Guidelines (Wilderness medical society practice guidelines)	NA	Blankets; quilts; sleeping bags; insulated pads; vapor barriers such as bubble wrap, tarp, sheet of plastic, reflective blanket, garbage bag; high-carbohydrate liquids and food; electric heat pads or blankets; large chemical heat pads; warm water bottles; charcoal-burning HeatPac; body-to-body rewarming; HPMK; heated humidified oxygen; distal limb warming; warmed intravenous fluids; forced-air warming; increasing ambient temperature in the ambulance	NA	Suggested general approaches to the evaluation and treatment of accidental hypothermia
[44]	Guidelines (State of Alaska)	NA	Insulation; vapor barrier; food or fluid containing sugars; chemical or electric heat pads; charcoal HeatPac; HPMK; mild exercise; body-to-body contact; forced-air warming; humidified and heated oxygen;	NA	Recommendations for treatment of cold injuries
[55]	Randomized controlled crossover experiment	N = 23	Heat ambulance mattress-prototype; unheated ambulance mattress-prototype	Back temperature; finger temperature; tympanic temperature; Cold Discomfort Scale; four statements from the state-trait anxiety inventory	A heated mattress results in increased comfort and may prevent hypothermia
[69]	Review	NA	Warmed intravenous fluids	NA	Warm intravenous fluids appear to keep patients warmer than room temperature fluids
[38]	Randomized controlled crossover experiment	N = 8	Woolen blanket; vapor barrier plus 1 woolen blanket; wet clothing removal plus 1 woolen blanket; 2 woolen blankets	Metabolic rate; esophageal temperature; skin temperature; heart rate; cold discomfort	Wet clothing removal or use of a vapor barrier limits the need for shivering thermogenesis and improves the patient's condition
[76]	Laboratory study	NA	Warmed intravenous fluids (warmed through: enFLOW, buddy lite, ThermoSens)	Fluid temperature	The enFLOW system heated saline faster than the ThermoSens
[77]	Laboratory study	NA	Warmed intravenous fluids (warmed through: ThermoSens)	Fluid temperature	The ThermoSens has good heating performance and is safe for red blood cell products
[79]	Laboratory study	NA	Warmed intravenous fluids (warmed through: ThermoSens)	Hemolysis marker; erythrocyte rheology parameters	The ThermoSens caused no erythrocyte injury or negative effects on rheology during heating
[34]	Laboratory study	NA	Ready-Heat II active rewarming blanket; Blizzard EMS blanket; bubble wrap thermal bag; space blanket; fire-retardant polyester ambulance blanket	Temperature of the thermal manikin	The Ready-Heat II heating blanket and Blizzard blanket were associated with lower rates of heat loss
[36]	Randomized controlled crossover experiment	N = 7	Single-layered polyethylene survival bag; single-layered polyethylene survival bag with a hot drink; multi-layered metalized plastic sheeting survival bag; multi-layered MPS survival bag with 4 large chemical heat pads	Core and skin temperature; metabolic heat production; energy expenditure; thermal discomfort	A multi-layered MPS survival bag reduces peripheral cold stress and shivering thermogenesis compared to a polyethylene survival bag; rewarming is aided by large chemical heat pads but not by hot drinks
[70]	Randomized controlled trial	Treatment group N = 26	Warmed intravenous fluids	Esophageal temperature	Intravenous fluid warming was associated with a smaller drop in core temperature than room temperature fluids
		Control group N = 26			
[74]	Laboratory study	NA	Warmed intravenous fluids (warmed through: exposure to body heat, leaving it in direct sunlight on a dark material, wrapping the giving set around gel heat pads, commercial fluid warmer)	Fluid temperature	The Buddy Lite reliably warmed the blood to a near normal physiological level
[54]	Laboratory study	NA	Ready-Heat II exothermic blanket	Temperature of the mannequin 'skin' and rate of rise in temperature	Supplemental use of oxygen in the presence of exothermic warming devices may represent a significant risk
[76]	Laboratory study	NA	Warmed intravenous fluids (warmed through: Mega Acer Kit, Ranger, ThermoSens)	Fluid temperature	Mega Acer Kit warms fluid more effectively compared with ThermoSens and Ranger at low flow rates; ThermoSens and Ranger are suitable at higher flow rates
[80]	Review	NA	Warm fluid ingestion	NA	

Table 2 (Continued)

Reference	Study type	Number of subjects	Treatment modalities for hypothermia	Outcome measures	Conclusion
					Modifying the temperature of an ingested fluid is not beneficial for modifying core temperature, but may be beneficial for improving the capacity to perform physical tasks

NA: Not Applicable; HPMK: Hypothermia Prevention Management Kit.

When clo = 1, this corresponds to the insulating value of clothing needed to maintain a person in comfort when sitting at rest in a room at 21 °C with air movement of 0.1 m/s and humidity less than 50%.

and polyester covers have a somewhat higher insulation value, but they are neither wind-resistant nor vapor-proof, and their insulation value is diminished in a windy and rainy environment [33,34].

Any vapor barrier provides the benefit of eliminating evaporative heat loss, decreasing convective heat loss and keeping any insulation dry (see Table 3). However, only vapor barriers made of thicker material or containing trapped air (e.g., a bubble wrap) are able to reduce heat loss [34–36].

The combination of an insulation layer and a vapor barrier such as Hot Pocket (the combination of two wool blankets and one Space Blanket inside a human remains pouch), is even more effective in the reduction of heat loss [33,35,37,38]. This combination of materials is incorporated in the insulated, non-reflective vapor barrier covers which are listed in Table 3.

Although insulating the spine board on which the patient is transported does not contribute to reduction of heat loss compared to an uninsulated spine board, it does result in a lower degree of estimated shivering [39].

External heat sources

In general, when external heat is applied to vigorously shivering (mildly hypothermic) subjects, skin warming inhibits shivering heat production by approximately the same amount of heat that is donated, such that core rewarming rates are similar between shivering only and external warming; if external heat is available there is still a benefit of increased comfort, and decreased energy requirements and cardiovascular work [40,41]. However, in moderate or severe hypothermia, where shivering is diminished or absent, active rewarming methods are required to rewarm the core effectively [31]. This means that heat must be generated from outside of the body and transferred to the patient. An overview of several active external rewarming devices is presented in Table 4.

Whenever possible, the temperature inside a transportation vehicle should be raised to at least 24 °C, to reduce further heat loss [42].

Multiple guidelines concerning the management of hypothermia recommend using electrical, chemical or charcoal-burning heat packs, and even body-to-body rewarming [42–44]. Also, the use of chemical heat packs and warm water bottles has been reported by prehospital services [45,46]. Heat packs can be applied at the axilla, chest or back of a hypothermic patient, since these locations provide the most efficient heat transfer by conduction [42]. In a study by Lundgren et al., two chemical heat pads (Dorcas AB, Skattkarr, Sweden) applied to the chest and upper back were compared with two flexible hot water bags applied to the same locations, and a charcoal heater (Normeca AS, Oslo, Norway) which was placed on the chest. All three rewarming methods significantly reduced the time taken to reverse core cooling, but hot water bags and the charcoal heater tended to rewarm patients faster than chemical heat packs ($p = 0.055$) [47]. The afterdrop, a phenomenon in which core temperature continuously decreases after removal

from the cold stimulus, was significantly reduced in subjects using the chemical heat pads and the hot water bags, but not in subjects using the charcoal heater. Other studies, however, showed that the charcoal heater did cause a decrease in afterdrop [40,48,49]. Heat donation through body-to-body rewarming can be accomplished by maximizing skin-to-skin contact between the back of a hypothermic patient and the front of a normothermic donor; this will not create a significant cold stress for the donor [41,48].

As discussed earlier, blankets can belong to the group of passive insulation interventions, however, active heating through electric blankets can rewarm a hypothermic patient [50,51]. A blanket that has only been warmed (e.g., in an oven) will quickly cool when applied to a cold patient and not provide any core warming [52]. The use of warmed water-perfused blankets is limited in the prehospital setting, but one mountain rescue team reported the use of a nylon circulating water blanket [46]. The water was heated by a camp stove and circulated by a modified bilge pump.

Specifications of other kinds of active heating blankets are listed in Table 4. The chemical Ready Heat pads and blankets (TechTrade LLC, New York, NY) effectively reduce heat loss, and the electrical heating blankets effectively rewarm subjects when they are applied in combination with another passive wrapping method, such as cotton blankets, wool blankets or a reflective blanket [50,51,53]. The Ready Heat blankets are activated by exposure to oxygen. Thus, when injured patients are supplied with oxygen, it could increase ambient oxygen levels and thereby intensify the heat production of the Ready Heat blanket up to 72.5 °C, which will rapidly cause thermal burns [54].

Additionally, the effects on heat loss reduction of a heated ambulance mattress prototype have been assessed; it increased back temperature and thermal comfort, but no statistically significant differences were found in finger and ear temperature, or on the cold discomfort scale [55].

Furthermore, forced air warming (the distribution of warm air through a blanket with perforations on the patient's side) has shown to be an effective rewarming method and in addition to its relatively high rewarming rate, it reduces afterdrop by 30 to 40% [48,56–59]. This method is already commonly used in hospitals, but although its application is recommended in guidelines concerning the prehospital management of hypothermia [42,48,56–58,60–62], and a portable cover has been designed for use in rescue vehicles [63], its prehospital use has not yet been adopted [45,64].

Heat sources with internal heat transfer

Warmed and humidified air or oxygen

The most common cause of accidental hypothermia is heat loss due to convective and conductive heat loss from the skin; however, a small portion of the heat is also lost through respiration as cold dry inspired air is warmed (via conductive and convective heat loss from the airways), humidified (via evaporative heat loss from airway lining fluids) and exhaled [65]. To oppose this heat and

Table 3

Overview of the insulation materials.

Cover type	Material	Manufacturer	Sizes (cm)	Sizes when packed (cm)	Weight (g)	Average price (USD)	Contributing to rewarming (yes/no/ND)	Contributing to the reduction of heat loss (yes/no/ND)	Level of evidence (reference; number of subjects)
Ultrathin covers									
Akla Metallic Foil Blanket	Dual surface metallic laminated plastic foil	Akla AB, Sweden	200 × 150	ND	60	ND	ND	ND	Not applicable
			Thickness 0.01 mm						
Mediwrap Metallic Foil Blanket	Metallic laminated plastic foil with inner textile lining	Mediwrap Ltd, UK	200 × 120	27 × 15 × 4	200	8 ^a	ND	ND	Not applicable
			Thickness 1.0 mm						
Plastic cover	Plastic	Multiple	200 × 150	ND	120	ND	No	No	Level 2 ([36]; N = 7)
		For example: Plastic sheet from two 125 l bin bags (grey) sealed together, Papyrus AB, Sweden	Thickness 0.03 mm						
Non-windproof, non-vapor proof covers									
Cotton blankets	100% cotton	Multiple	Available in various sizes: Twin: 168 × 229 Full/Queen: 229 × 229 King: 274 × 229	Varies with size	Lightweight: 200–240 Medium: 320–380 Heavyweight: >400	Starts from ±20	ND	ND	Not applicable
Wool blankets	100% wool	Multiple	190 × 135	ND	2070	ND	ND	ND	Not applicable
		For example: Rescue Services Wool Blanket, Swedish Rescue Forces Surplus Army Surplus World, Inc. Houston, Texas							
	Wool-blend fabric (70% new wool and 30% synthetic materials)		157 × 208	ND	2000	39.99	No	No	Level 5 ([35]; N = 2)
Polyester ambulance blanket	100% polyester	Thomas Kneale, Manchester, UK	170 × 228	ND	ND	ND	No	Yes ^b	Level 5 ([34]; N = 5)
Non-insulated, non-reflective vapor barrier covers									
Bubble wrap	Plastic	Multiple	For example with Uline: 122 × 11430 Thickness: 8 mm	For example with Uline: ND	For example with Uline: 8845	For example with Uline: 131	No	No	Level 5 ([34]; N = 6)
		For example: Uline, Wisconsin, United States							
Human remains pouch (body bag)	The one used by Allen et al. [35]	Not described for the human remains pouch used by Allen et al. [35]	ND	ND	ND	ND	No	No	Level 5 ([35]; N = 2)
Non-insulated, reflective vapor barrier covers									
Space blanket (combat casualty care blanket)	Metalized polyethylene terephthalate	Multiple	142 × 213 ^c	2.5 × 10 ^c	85 ^c	6.24 ^c	No ^d	Yes ^d	Level 5 ([35]; N = 2)
									and Level 5 ([34]; N = 6)
Blizzard blanket	Reflexcell™	Blizzard Survival Blanket, Blizzard	235 × 240	20 × 11 × 4.5	525	34	No	Yes ^e	

Table 3 (Continued)

Cover type	Material	Manufacturer	Sizes (cm)	Sizes when packed (cm)	Weight (g)	Average price (USD)	Contributing to rewarming (yes/no/ND)	Contributing to the reduction of heat loss (yes/no/ND)	Level of evidence (reference; number of subjects)
		Protection Systems, Gwynedd, UK							Level 2 ([36]; N = 7) Level 5 ([35]; N = 2) Level 5 ([34]; N = 6) Level 5 ([35]; N = 2)
Heat Reflective Shell (HRS™)	4-ply composite fabric with non-conductive reflective layer	North American Rescue Products, Greer, SC	198 × 110	25.4 × 17.1 × 6.4	822	54.99	No	Yes	
Insulated, non-reflective vapor barrier covers									
RC20® Rescue blanket	Nylon outer with synthetic filling and cotton inner	Help&Rescue AB, Sweden	220 × 140	ND	1910	ND	ND	ND	Not applicable
			Thickness 6.8 mm						
Fly High® Rescue Blanket	Nylon outer with synthetic filling and cotton inner, with a hood and an outer margin elastic cord	Help&Rescue AB, Sweden	275 × 124	ND	2320	ND	ND	ND	Not applicable
			Thickness 6.8 mm						
RC42© Rescue Bag	Nylon outer with synthetic filling and cotton inner	Help&Rescue AB, Sweden	220 × 140	ND	5940	ND	ND	ND	Not applicable
			Thickness 25 mm						
MARSARS Hypothermic Stabilizer Bag	Deep pile lining insulates and wicks water away from patient	MARSARS Water Rescue Systems, Inc., Shelton, Connecticut	210 × 76	ND	4762	ND	ND	ND	Not applicable
			Top Outer Shell: Thickness Inner liner: 28 mm 240 denier Nylon Bottom Outer Shell: 1000 denier Cordura						
Doctor Down® Rescue Wrap® Emergency Orange	Loaded with 2 Primaloft® insulated cores; top and bottom shell and 1 set of disposable liners	Doctor Down, Inc., Polson, Montana	94 × 203	ND	6350	800 (together with 1 large and 1 small reusable heat pack)	ND	ND	Not applicable
Victims Casualty Hypothermia Bag	A bottom of 1000-denier cordura; a lining and top of 200 denier oxford nylon; with insulation layer of 340 g	Wiggy's Inc., Grand Junction, Colorado	254 × 091	30.5 × 63.5	3629	335	ND	ND	Not applicable

ND Not described.

^a For this price available at https://www.spservices.co.uk/item/Mediwrap_MediwrapHighProtectionBlanket-AdultSize_0_46_1000_1.html.^b Heat loss of 6.1 °C over a period of 60 min.^c Grabber Outdoors.^d Blanket, Combat Casualty, Type II (Space Blanket). Heat loss of 1.9 °C over a period of 120 min [35]. Heat loss of 4.5 °C over a period of 60 min [34].^e Heat loss of 1.4 °C over a period of 120 min [35]; Heat loss of 2.1 °C over a period of 60 min [34]; The metabolic heat production in subjects using the Blizzard Survival Bag was not different from shivering near-hypothermic controls seated in an ambient temperature of 20.2 °C without any insulation material [36].^{*} consisted of an outer plastic or canvas cover with a rubber leak proof inner core. Constructed from a polyolefin, 4-ply, composite fabric with a protected nonconductive thermal reflective layer.

Table 4

Overview of the external heat sources.

External heat source	Product	Sizes (cm)	Weight (g)	Average price (USD)	Duration of heat delivery	Maximum temperature (°C)	Rewarming rate (°C/h)	Contributing in the reduction of heat loss (yes/no/ND)	Level of evidence (reference; number of subjects)	Comments
Heat packs										
Electric heat pad	HK 67 To Go (Beurer GmbH, Ulm, Germany)	49 × 33	ND	66	After 6 h of charging it will deliver 2 h of cordless heat	65–70	ND	ND	Not applicable	
Charcoal heater	The HeatPac Personal Heater (Normeca AS, Oslo, Norway)	Combustion chamber: 23 × 12 × 6	Combustion chamber: 500	300 ^a	8–12 h	45–70	0.7	Yes	Level 2 ([48]; N = 6)	This device consists of a combustion chamber and four tubes that can be wrapped around the chest. A battery-powered fan distributes warmed air over the tubes. There is no risk for carbon monoxide poisoning when the exhaust hose is placed correctly [48,66]
Chemical heat pack	Heat Wave (Bent Grass Concepts, USA)	Tubes: Length 115 Width 12 20 × 30	Tubes: 150 each 793	33.99	1–2 h	54.4	ND	ND	Not applicable	Reactivate by boiling in water for 15+ minutes; Level 3 ([47]; N = 5) evidence exists for a rewarming rate of 0.2 °C/h with chemical heat packs from Dorcas AB, Sweden
Hot water bags	Dromlite™ bags (Mountain Safety Research, Seattle, Washington)	28 × 56	162	39.95	20 min	Depends on how long the water is boiled	0.7	Yes	Level 2 ([47]; N = 5)	The water can be heated with a portable stove such as the PocketRocket Stove (Mountain Safety Research, Seattle, Washington) (see Table 5 for its specifications)
Heated blankets										
Chemical heating blanket	Ready-Heat™ Blanket (TechTrade LLC, New York, NY)	86 × 122 ^b	680 ^b	23.99 ^c	8–10 h	37.8	0	Yes ^d	Level 5 (two studies: [34]; N = 5 and [35]; N = 2)	Needs 10–30 min to get warm; Produces heat when it is exposed to air
Chemical heating blanket	Barrier EasyWarm autoactive heating blanket (Mölnlycke Health Care, Göteborg, Sweden)	152 × 92	684	ND	10 h	44 °C	ND	ND	Not applicable	Needs 30 min to reach 44 °C; Produces heat when it is exposed to air
Electric heating blanket	Carbon-fibre resistive heating blanket ⁺⁺ (ThermaMed, GmbH, Hamm, Germany)	80 × 200	Batteries: 500 Blanket: ND	ND	Batteries last 30–40 min	42	Carbon-fibre blanket only: ND In combination with a wool blanket: 0.8	Carbon-fibre blanket only: ND In combination with a wool blanket: Yes	Carbon-fibre blanket only: Not applicable In combination with a wool blanket: Level 2 ([50]; N = 100)	
Electric heating blanket	UniqueResc ⁺ Rescue	Small: 48 × 49	Small: 500	ND	Unlimited as long as a power	Small blanket: 40	ND	ND	Not applicable	Reusable; average life time of 5 years

Table 4 (Continued)

External heat source	Product	Sizes (cm)	Weight (g)	Average price (USD)	Duration of heat delivery	Maximum temperature (°C)	Rewarming rate (°C/h)	Contributing in the reduction of heat loss (yes/no/ND)	Level of evidence (reference; number of subjects)	Comments
	Warming System ^{**}				source of 12–24/28 V is available					
	(Geratherm Medical AG, Geschwenda, Germany)	Medium: 50 × 86	Medium: 900			Medium blanket: 37–40				
Electric heating blanket	ChillBuster model 8001 (ThermoGear, Inc., Tigard, Oregon)	Blanket: 76 × 152 Controller: 21 × 8	3629	59.99 ^e	Batteries last for 1.75–3.5 h	40.6	ChillBuster only: 0	ChillBuster only: ND	Level 5 ([51]; N = 20)	
							ChillBuster with a reflective blanket: 0.25	ChillBuster with a reflective blanket: Yes		
Forced air warming	3 TM Bair Hugger TM model 775 (3M Health Care Ltd, Leicestershire, UK)	Heating unit: 33 h x 36 w x 33 d	Heating unit: 7300	1295 ^f	Unlimited	Operating Temperature:	2.4 ± 1.0	Yes	Level 2 ([58]; N = 16)	A rigid cover provides higher core warming rates than the usage of a soft cover [48]
		Blankets available in various sizes				High: 43 ± 1.5 Medium: 38 ± 1.5 Low: 32 ± 1.5				

ND Not Described.

^a For this price available at <http://www.hawills.com/>.^b Ready-HeatTM II Blanket.^c For this price available at <http://www.buyemp.com/product/ready-heat-blankets>.^d The temperatures of torso models decreased 0.94 °C in one study and 0.8 °C in the other study, over a period of 120 and 60 min respectively.^e For this price available at <https://www.keystoneenterprises.com/thermogear-chill-buster-themal-portable-rechargeable-electric-blanket-mdl-8001.html>.^f For this price available at <https://mfimedical.com/products/3m-bair-hugger-model-775-warming-unit>.^{*} It seems like the manufacturer of the assessed heat packs (Dorcas AB, Sweden) does no longer exist. Therefore, specifications of other chemical heat packs are listed in this table.^{**} Thermamed has been taken over by Geratherm. Geratherm further developed the carbon-fibre resistive heating blanket and currently this company sells an electric heating blanket especially designed for prehospital use (UniqueResc⁺ Rescue Warming System).

water loss, the administration of warmed and humidified inhaled air or oxygen is recommended by the International Commission for Mountain Emergency Medicine and the Wilderness Medical Society Practice Guidelines [42,43]. However, studies have shown that inhalation rewarming did not improve rewarming rate or decrease afterdrop [56,66,67].

Warmed intravenous fluids

It is known that trauma patients who receive blood during prehospital transport are more likely to arrive in a hypothermic state [68]. Infusion of warmed intravenous fluid minimizes the negative heat balance [52,69–71]. Therefore, it is recommended to warm intravenous fluids to 38–42 °C prior to infusion when fluid or blood are administered, to prevent cooling of the patient [72,73]. Portable battery-operated inline intravenous fluid warmers, a warmed cabinet in the ambulance, and insulated wraps around the intravenous tubing and solutions can be used to warm infusion fluids as long as they are commercially built for this purpose and proved effective under the environmental conditions in which they will be used. Table 5 provides an overview of the different

equipment types used for the warming of intravenous fluids and their effectiveness. Warming packed red blood cells for five minutes either in the axilla of a normothermic person or on a black carbon spinal board in direct sunlight raised the temperature significantly, namely from 4 °C to 17.2 °C and 20.2 °C respectively [74] but these temperatures are still far below the required 38–42 °C.

Among battery-powered inline fluid warmers, the ThermoSens (Sewoon Medical Company, Seoul, Korea) demonstrated effective warming of cold (5 °C) infusion fluids up to an outlet temperature varying from 37.6 °C to 39.3 °C at different flow rates (varying from 30 to 100 ml/min) and it can safely be used for red blood cell products [75–78]. Under the same conditions, the enFLOW (GE Healthcare, Piscataway, NJ, USA) was shown to warm fluids up to a temperature varying from 37.1 °C to 41.1 °C. The ThermoSens and enFLOW performed better than the Buddy Lite (Belmont Instrument Corporation, Billerica, MA, USA), which was not able to maintain the outlet fluid temperature above 36 °C at flow rates above 30 ml/min [76]. At low flow rates (below 14 ml/min), the Mega Acer Kit (Ace Medical, Seoul, Korea) warmed fluids more effectively than the

Table 5
Intravenous fluid warming devices.

Intravenous fluid warming device	Manufacturer	Sizes (cm)	Weight (g)	Average price (USD)	Battery duration	Mechanism of heat production	Maximum temperature to which fluids are heated (°C)	Flow rate	Contributing in intravenous fluid warming (+/–)	Level of evidence (reference)	Comments
Flameless Ration Heater (chemical heat pack)	TrueTech Inc, Riverhead, NY	8.9 × 11.4 × 0.318	Typical sac: 21 Paperboard cover: 9	12.00 for a 12-pack ^a	No batteries required	Chemical; activated by adding a small amount of water (90–150 ml)	ND	NA	+ ^b	Level 5 (Two studies: [84,85])	Takes 5–11 min to heat intravenous fluid bags (from 500 ml and 1 l)
The PocketRocket™ Stove	Mountain Safety Research, Seattle, Washington	10.2 × 5 × 5.1	85	39.95	No batteries required	Warm water heats a fluid bag	Depends on boiling-time of the water	NA	+ ^c	Level 5 [84]	Boils 1 l of water in under 3.5 min; Heats intravenous fluid bags (from 500 ml) in 5–8 min; Only 500 ml fluid bags fit
Battery powered inline fluid warmers Thermal Angel	Estill Medical Technologies, Dallas, Texas	Heater Unit: 23 × 7 × 2	Device: 260	642.50 ^d	ND	Electrical	38 °C	Input temperature 20 °C: KVO to 150 ml/min	+ ^e	None	Warms within seconds
Belmont® buddy lite™	Belmont Instrument Corporation, Billerica, Massachusetts	Ultra-Battery: ND Heater Unit: 3.8 × 13.2 × 2.2 Battery: 8.4 × 19.1 × 3.1 AC/DC Supply: 10.8 × 21.3 × 4.7	Ultra-Battery: 567 Heater unit, battery and battery housing: 730 AC/DC Supply: 1200	1400 ^e	A single battery can deliver 4.4 l of warmed fluids with a temperature of 38 °C	Electrical	38 °C	Input temperature 20 °C: max 80 ml/min (crystalloids) Input temperature 10 °C: max 50 ml/min (packed red cells)	+ ^f	Level 5 [74]	Warms within seconds
QinFlow Warrior	QinFlow Ltd., Kibutz Einat, Israel	Heater Unit and battery: 1.91 (0.0019 m ³)	Base unit: 700 Disposable unit: 125 Battery: 908	ND	A single battery can deliver 3–5 l of warmed fluids (depends on flow rate and input fluid temperature)	Electrical	38 °C	Input temperature 4 °C: KVO to 200/290 ml/min	+ ^g	None	Warms within seconds
ThermoSens	Sewoon Medical Company, Seoul, Korea	Heater Unit: 5.9 × 12.6 × 3.7	Heater Unit: 104	ND	5.5 Ah; 50 min with a flowrate of 80 ml/min	Electrical	41 °C	KVO to 150 ml/min (guaranteed output temperature of 36 °C with an input temperature of 20 °C)	+	Level 5 [75,76–78]	Warms within seconds
enFLOW	GE Healthcare, Piscataway, NJ, USA	Battery: 8.2 × 19.6 × 4.2 Warmer: 13 × 6 × 3 Cartridge: 4 × 11 × 1	Battery: 540 Warmer: 279 Cartridge: 33	ND	ND	Electrical	40 °C	Input temperature 20 °C: KVO to 200 ml/min	+	Level 5 [76]	Warms within seconds

Mega Acer Kit	Ace Medical, Seoul, Korea	Controller: 23 × 15 × 9 ND	Controller: 1800 ND	NA	ND	Electrical	36 °C	ND	+	Level 5 [75]	It was not described to operate on batteries
Ranger	Arizant Healthcare, Inc., MN, USA	Warming unit: 19 × 11 × 25	Warming unit: 3300 unit	NA	ND	Electrical	41 °C	Input of room temperature fluids: KVO to 500 ml/min	+	Level 5 [75]	It was not described to operate on batteries

ND Not Described; NA Not Applicable.

^a No studies found.

^b Price listed at <http://theepicenter.com/mre-flameless-ration-chemical-heaters-dozen.html>.

^c Heated intravenous fluids to a temperature within the range of 39.7 °C–45.6 °C.

^d Heated intravenous fluids to a temperature within the range of 35 °C–40 °C.

^e Price listed at <http://www.usamma.amedd.army.mil/assets/docs/6515-01-500-3521%20BLOOD%20FLUID%20WARMER%20THERMAL%20ANGLE%2030%20aug%2007.pdf>.

^f Price listed at <http://www.cedar.wales.nhs.uk/sitesplus/documents/1091/CEP10014%20IV%20fluid%20warming%20MR.pdf>.

ThermoSens and Ranger (Arizant Healthcare, Inc., MN, USA), but this effect was reversed at higher flow rates (above 19 ml/min) [75].

One experimental study tested a lightweight mobile system for extracorporeal circulation in pigs during prehospital transport. Although it raised rectal temperature of these pigs from below 20 °C to over 37 °C in a time period ranging from 38 to 85 min, this invasive rewarming method does not seem feasible for prehospital use [79].

Warm or high-carbohydrate drinks

Ingesting a warm drink will not provide a significant thermal benefit to the body's core [36,80]. In fact, a warm drink may temporarily inhibit shivering through the competing responses of increasing comfort in contrast to its effectiveness, which results in a decreased heat balance [80]. However, a drink with high-carbohydrate content will fuel shivering and thus heat production, which will minimize or prevent further core cooling [29,42].

Discussion

The current practice of prehospital hypothermia management is based on considerable laboratory research but minimal controlled studies on actual patients in the field. In contrast, in-hospital management of cold patients has been studied more thoroughly; effective rewarming methods are available for in-hospital use, such as warm fluid lavage of body cavities or extracorporeal rewarming [81]. Extracorporeal rewarming can be accomplished by hemodialysis, continuous arteriovenous rewarming, continuous venovenous rewarming or cardiopulmonary bypass, with each method having advantages and disadvantages [73,81]. The practicality of these invasive rewarming methods is limited in the prehospital setting and therefore, we sought the most useful rewarming strategy that can be applied in a prehospital environment.

Any cold patient should be removed from the cold stress (as gently as possible), kept as horizontal as possible, dried (when protected from the cold environment), insulated from the ground, and placed in a hypothermia wrap consisting of insulation, a vapor barrier and preferably a heat source. In a mildly hypothermic vigorously shivering patient (who is able to create endogenous heat), the combination of a thick insulation layer (for example wool blankets) together with a vapor barrier may be sufficient as they may warm themselves through shivering heat production [33,35,37,38]. Active heating may not be necessary but will still provide advantages of decreasing the energy requirements and cardiac work of shivering and provide a distinct comfort advantage. In moderately or severely hypothermic patients, who are not shivering and have very little endogenous heat production, active heating is necessary to rewarm the patient, for example by applying chemical heat packs inside the insulation/vapor barrier material [36]. For example, the Hypothermia Prevention and Management Kit (North American Rescue Products, Greer, SC), which contains a Ready Heat blanket and a Heat Reflective Shell (HRS), is recommended by the committee on Tactical Combat Casualty Care [82]. Other effective active rewarming methods include a charcoal-burning heat pack, hot water bags and electrical heating blankets. External heat should be applied on the axilla, chest and/or back (if possible), as these are the locations that provide the most efficient heat transfer [42]. However, application of heat packs at the back will not be possible in a patient in full spinal precautions, because of the risk of malalignment of the spine. Although warming with forced air has shown to be effective, its prehospital use is still limited to transport vehicles. Some external rewarming methods pose a risk of burning the skin if they are applied directly. Therefore, one should always follow manufacturer's directions for

use, especially if they suggest placing appropriate insulation between the heat and the skin.

Additionally, when it is necessary to infuse fluids intravenously in a hypothermic patient, heating these fluids prior to infusion is essential to prevent active cooling of the patient's core. Also, since the infusion of fluids with a temperature higher than 40 °C is not without risks of endovascular damage [81], and patients generally do not receive large volumes of intravenous fluids prehospital [83], this intervention is unlikely to significantly rewarm a hypothermic patient although infusion of 'room temperature' fluids (20–22 °C) may cool the patient. Among the different intravenous fluid warming strategies, battery-powered inline fluid warmers are easy to use, and warm the fluids in a more controlled way than chemical heat packs or stoves. One prerequisite is that the inline fluid warmer is placed close to the patient, to reduce the heat loss from the distal tubing. The magnitude of this heat loss depends on several factors such as flow rate of the fluids, and the diameter and length of the tubing; this should be taken into account when using these devices.

Although some randomized controlled trials have been performed on cold subjects and there is considerable laboratory-based evidence for the discussed treatment modalities, there remains a lack of randomized controlled trials conducted in the actual pre-hospital setting with a large sample size. It is therefore essential that this type of research is performed to assess and compare the effectiveness of the discussed treatment modalities in the prehospital setting, expressed in their effects on body core temperature, as well as in other patient outcomes.

Limitations and strengths

This article provides an up-to-date systematic overview of interventions used for the management of hypothermia in the prehospital setting, after the last review on this topic was performed 16 years ago. A broad literature search was performed by searching multiple databases, using broad search terms without limitations on publication dates.

It is hard to combine the available data and consequently make recommendations about the usefulness of each treatment modality because of the differences in study designs. Studies differ in aspects such as study environment (ambient temperature and wind conditions), study subjects (mildly or severely hypothermic patients, healthy volunteers or fluid bag models), focus of the outcomes (heat loss reduction, rewarming rate, metabolic heat production or thermal comfort), locations of measuring body temperature, the period of rewarming, and the measurement points. Some studies do not have a control group, making it difficult to compare results to other studies.

Conclusion

On the basis of our literature review it can be stated that the best way to manage hypothermia in a prehospital setting is to reduce further heat loss by placing the patient in a warm and dry environment and applying insulation in combination with a vapor barrier. The addition of an active rewarming method such as heat packs or blankets is not compulsory in vigorously shivering patients who will likely warm up eventually, but must be considered when treating severe hypothermic patients who will not rewarm on their own. Hypothermia wraps that include the most insulation (e.g., MARSARS, Dr. Down, Wiggy's, hooded sleeping bags) and have the greatest external heat sources (e.g., chemical heat packs, charcoal heater etc.) are the most effective. Although no single combination has been demonstrated to be

significantly better than all the others, adequate data are available to choose the best hypothermia wrap for a given agency, based on efficacy, cost, volume and weight. In addition, intravenous fluids should be warmed (confirmed to 40 °C) before administration to reduce heat loss. The battery-powered intravenous fluid warmers are currently the most practical devices for warming of intravenous fluids in the prehospital phase. Further research on this topic should concern large randomized controlled trials conducted in the pre-hospital setting.

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Data collection: F.H., E.T.

Data analysis: F.H., E.T., G.G.

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