

The most effective method of cooling a soldier suffering from exertional heat stroke

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Abstract

Soldiers are often physically pushed to their limits in order to prepare and condition themselves to survive in war. In hot climates this physical exertion can lead to exertional heat stroke (EHS). Rapid and efficient cooling is the most important therapeutic objective in patients with EHS. The purpose of this review is to find the most effective method of cooling a soldier suffering from EHS. The literature search conducted included articles between 1985 and 2009. The databases searched were CINAHL plus, Cochrane Library, Science Direct, Pub Med, Ovid, Medline and Proquest. A manual search of reference lists was also conducted. Literature was included if it contained comparisons of different cooling methods in either patients with EHS or normal participants who were subjected to heat stress in experiment conditions. A total of 15 articles were selected. Careful analysis of the articles obtained indicated that the most effective method of cooling a soldier suffering from EHS is ice water immersion. In conclusion the evidence presented supports the Australian Defence Forces new Health Directive that advocates the use of ice water immersion. It is also evident from the literature that further prospective studies would be beneficial as they examine actual EHS cases rather than healthy participants in experiment conditions.

Keywords: heat stroke, exertional heat stroke, heat illness, cooling techniques, ice water immersion and military.

Introduction

In 2008 the Australian Defence Force (ADF) introduced a new Health Directive to manage and treat heat casualties within the Defence Force.¹ Heat hazards pose a significant threat to Defence personnel due to the nature of work and training, therefore exposure to high levels of heat stress is imminent. Currently, the ADF has preventative measures in place to help in the prevention of heat stress such as heat acclimatization, fluid and electrolyte replacement, exercise/rest guidelines, using the early hours of morning for strenuous

activity to avoid the day time heat and vigilance, EHS can still occur. EHS is defined as a life threatening condition that occurs when the accumulation of heat dramatically exceeds the body's ability to dissipate heat due to a failure of the hypothalamus.² Characteristics of heat stroke include a core body temperature of greater than 41.0°Celsius (C), dry skin, hypotension, tachycardia, neurological dysfunction such as delirium, confusion, convulsions, unconsciousness and coma.^{1,4} When the core body temperature reaches critical levels, body organ systems begin to fail. The prognosis for EHS depends upon the length of time and degree that the core temperature is elevated. The definitive management goal of EHS is to reduce the core body temperature to a safe level of below 38.5°C as quickly as possible.

The purpose of this literature review is to determine the most effective cooling method for a soldier suffering from EHS. The review will focus on cooling methods and provide comparisons of cooling times used for EHS. The second purpose for this review is to explore evidence that may support the new ADF Health Directive¹ which encourages the use of ice water immersion in the treatment of EHS.

Method

A comprehensive search of the literature was carried out using the databases CINAHL plus, Cochrane Library, Science Direct, Pub Med, Ovid, Medline and ProQuest. The search terms that were used; heat stroke, exertional heat stroke, heat illness, cooling techniques and ice water immersion. Keywords were

used on their own and with the word military added to find specific articles. Limits were also placed on the search being human subjects and published after 2000. A manual search of reference lists was also conducted and from this several articles of relevance were found that were dated pre 2000. Therefore the search limits were extended to 1985 –current. These studies were included as they are directly related to the topic for investigation and they support the more current literature selected for the review. Literature was included if it contained comparisons of different cooling methods in either patients with heat stroke or normal participants who were subjected to heat stress in experiment conditions. Articles were based on soldiers and athletes as both groups have similar physical characteristics such as fit, healthy and athletic. A total of 15 articles were selected.

Discussion

The main objective in the management of EHS is to reduce the body temperature to a safe level as quickly as possible. The two main forms of cooling utilised and discussed in the literature to date are conduction and evaporative methods:

1. Conduction is the passive transfer of heat from the body into the surrounding air, liquid or solid in contact with the skin along a temperature gradient.³ Conduction cooling includes methods such as cold water immersion, ice water immersion, application of ice packs and cooling vests.

2. Evaporative cooling is based on the physical principle that the conversion of water on the skin to a gaseous phase consumes

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heat.³ Therefore as air is forced onto the skin when wet it will consume some of the heat from the body. Evaporative cooling can include fan forced, sitting the patient in the shade, fanning and helicopter downdraft.

Several studies to date have directly compared conduction and evaporative methods.^{2, 4-7} Clements et al² conducted a random crossover study to assess whether ice water immersion, cold water immersion or no immersion is the more effective cooling method in trained distance runners. Although this was limited in terms of the small homogenous sample ($n=17$) it clearly showed that ice water was faster than cold water in cooling a hyperthermic runner. It was also evident that ice water and cold water immersion were more effective than no immersion at all. With approval of the Local Institutional Review Board for Human Subjects, Armstrong et al⁴ also conducted a Randomized Control Trial (RCT) where twenty one distance runners completed an 11.5km race and were then randomly assigned to either conduction cooling (ice water immersion) or evaporative cooling (air exposure while wrapped in towels). Armstrong et al⁴ believe ice water immersion is the more effective cooling method and for that reason they randomly assigned 14 participants to ice water and only 7 to air exposure. This presents a threat to internal validity as the results are based on uneven randomisation of participants. The results of this study⁴ showed that ice water immersion cooled the runners twice as fast as air exposure. Armstrong et al⁴ present reliability in their study in that it can be repeated due to the nature of the independent variable (ice water immersion and air exposure) and the measuring instrument (rectal thermometer). Similar results were also found in other studies.⁵⁻⁷ Clapp et al⁵ conducted a repeated measure design study on five participants to determine which method of cooling is more effective between torso immersion in cold water, hands and feet immersion and sitting in the shade. The results revealed torso immersion to be most beneficial, evidenced by the cooling time of 0.25°C/min, hands and feet 0.16°C/min and sitting in the shade 0.11°C/min. The small subject size ($n=5$) and homogenous sample does make it difficult to generalise the results.

Lopez et al⁶ conducted a study consisting of 10 participants. After exercising to a core temperature of greater than 38.7°C half of the participants put on a cooling vest and half did not. The results showed the cooling vest was effective, however when the cooling time of the vest were compared to previous studies with ice water immersion, it was found that immersion was by far a more effective means to cool the body. Limitations to this study included females being excluded and all participants had to be a similar weight and height, therefore it is difficult to generalise the findings. Finally due to ethical and safety concerns the study limited the increase in core body temperature to less than 39°C, which is in fact only mild hyperthermia, EHS occurs in core temperatures exceeding 41.0°C.¹

Taylor et al⁷ with approval from the Human Research Ethics Committee conducted a random cross over study in which eight healthy, physically active males participated. Once their core temperature reached 39.5°C they were exposed to air, cold water immersion (14°C) or temperate water immersion (26°C). The results found that cold water immersion was

the most effective. Reliability is achieved in this study as the instrument used (esophageal thermometer) meant there would be no carry over effects as the instrument is objective in nature. A limitation to this study is that it was conducted indoors in an air conditioned environment; thus threatening the internal validity as the air conditioning may affect the independent variable (cold and temperate water).

Although not comparing conduction and evaporation Proulx et al⁸ compares four different water temperatures 2°C, 8°C, 14°C and 20°C with seven healthy subjects. The participants exercised until their core temperatures reached 40°C. Participants were exposed to all four water temperatures on four separate days. The results showed that the 2°C water cooled the participants twice as fast as the other water temperatures. The limited size, selection criteria and controlled environment of a laboratory would make the results difficult to generalize. This again supports the evidence that cold/ice water immersion is the most effective cooling method. McDermott et al⁹ conducted an observational study for five consecutive years at Marine Corps marathons. During this period they observed the onsite treatment for nine EHS patients. Treatment consisted of dousing the patient in water and massaging their bodies with ice. The results found this form of cooling to be 70% as effective as cold water immersion. This study is limited in terms of sample size however the patients are direct examples of military members suffering EHS.

Costrini¹⁰ advocates the use of ice water immersion after he conducts a retrospective review of whole body cooling techniques. Costrini was a Marine Corps Medical Officer who treated 39 patients with EHS using an ice water bath. The patient's temperatures ranged from 41.1°C to 43.1°C. The ice water bath resulted in a 0.15°C/min decrease in core temperature. All patients returned to normal active duty with no renal or other organ failure. This study provides sound evidence that ice water immersion is the most effective as they are treating real life cases of heat stroke in the environment in which they occur. Harker and Gibson¹¹ who are two Military Nursing Officers in the UK, reviewed rapid cooling techniques to support what practices are currently being used in military hospitals. They conducted an informal study on doctors and nurses ($n=25$) within their own hospital all of which clearly preferred ice water immersion as a cooling method; they argue that the basic rationale is that the ability of water to conduct heat is much greater than that of air.¹¹

Several other studies¹²⁻¹⁶ all conclude that ice water immersion is the most effective method for treating EHS when compared to other forms of cooling such as ice packs, evaporation and intravenous fluids. Boucharma³ concludes that the cooling method based on conduction, namely ice water immersion started within minutes of the onset of EHS, was safe and effective in young, healthy well-trained military personnel or athletes.

Several studies^{2, 5, 10, 12-14, 16} stress that treatment should begin at the time of collapse. Although ice water immersion may be the most effective method of cooling a soldier it is not practical in the field environment.^{10, 14} If a soldier collapses in the field and ice water immersion is not available in order to prevent further increase in temperature, removing excess clothing, placing in the shade, dousing in water and fanning

may be life saving measures until the casualty is evacuated to a medical facility where ice water immersion is practical. Studies^{7,13} have also shown that temperate water does decrease core body temperature. Although not as effective as ice water immersion, soldiers do carry limited amounts of water for drinking and cleaning and this may be a life saving measure in the field environment. Soldiers can be hours away from a medical centre therefore O'Hara et al¹⁴ recommend further testing and implementation of the Carotid artery-cooling patch (CACP). The CACP is a small device carried easily in a soldiers pack and placed over the carotid artery in hot conditions. The CACP is based on cooling along the carotid artery and surrounding tissue which enhances blood flow to the head and neck and decrease the chances of brain ischemia.¹⁴ A limitation to this is there are no studies to date to support the use of the CACP. Smith's systematic review of the literature¹² also supports the use of ice water immersion however notes that it is impractical for soldiers in the field and athletes that collapse on the roadside and away from immediate medical attention. This review may be subject to publication bias as all included experiments had the desired outcome.

In reviewing the ADF Health Directive¹ it is evident that it addresses to a degree, ice water immersion for soldiers in the field environment. On military bases an ice machine will be available and ten kilogram bags of ice will be prepared daily for pick up by all training platoons to take to the field for the day. The ice will be stored in an esky and will be utilised in the case of heat illness. A 'hoochie' (hoochie is a military slang term used to describe an individual soldiers sleeping shelter. It is a 2 metre by 4 metre water proof shelter carried by all soldiers) will be used as the immersion bath, by having other soldiers hold up the corners of the hoochie whilst the casualty lies in it and is covered with water and ice. This system is referred to in the ADF Health Directive¹ as the 'Taco method' (due to the fact it looks like a taco) and may be enough to cool the patient until they reach medical help. Although this is a good method to adopt, the question remains as to how long the ice will stay frozen in 40°C temperatures even in the esky. However even if it is only water, it is the coldest cooling mechanism available and the key element of EHS is to decrease core body temperature. In addition this review highlights the fact that although ice water immersion is the most effective method for cooling soldiers on military bases, other methods of cooling may need to be adopted in the field environment. Future research should focus on practical cooling devices that can provide rapid cooling effects of soldiers training in the field and working in war zones.

In reviewing the outcomes of the incorporated literature it also becomes evident that most of the quantitative literature is based on healthy volunteers in experimental conditions such as Randomised Controlled; cross over and repeated measure trials. Soldiers undergoing training are often sleep deprived, living on minimal food and sometimes already dehydrated, their bodies are already stressed and not functioning at peak condition. In contrast to this a healthy participant in an experiment is fit, healthy, well rested, hydrated and nourished. Therefore the question has to be raised; are healthy participants in EHS studies true reflections of EHS and can the results of these studies be used as sufficient evidence to support ice water immersion.

RCT's are considered high quality in terms of evidence; however in relation to EHS it may be difficult to generalize the results. Six RCT's were included in this review; ^{2, 4-8} all trials used participants who were healthy, young volunteers. They were exercised under experiment conditions until their core temp reached less than 40°C in four of the studies^{2, 5-7} and 41°C in two of the studies.^{4, 8} With heat stroke being defined earlier as a core temperature over 41°C the issue is raised as to whether the four experiments with peak core temperatures of less than 40°C can be used as substantial evidence. However in exploring this further it is hard evidence in the included RCT's that ice water immersion is the most effective cooling method. Whether the patient's temperature is 38°C or 41°C, ice water is going to be the most effective method of cooling based on the principle of conduction alone, irrespective of peak core temperature.

In addition to RCT's, it would be worthwhile considering future research to be based on prospective cohort studies. For example if all ADF Health facilities record the outcomes and cooling times of real EHS patients over the next two years using ice water immersion and evaporative methods, the data collected could be used as substantial evidence of the effectiveness of ice water immersion. These cases are true reflections of EHS in soldiers and how the body adapts.

Implications to Nursing Practice

Nursing staff working within the ADF are often faced with patients suffering from EHS due to the nature of military training. The potential significance of this literature review to nursing scholarship is that it will allow for the most effective and rapid method of cooling a soldier to be utilised. The focus group for this study is military personnel however the results of this literature review can be generalized to athletes in sporting events and marathons as they have similar physical characteristics. As can be seen from this literature review these results could potentially be used as part of the evidence to develop a national or even universal policy for treating heat illness. This review can be used as evidence to support the new ADF Health Directive into the management of EHS.

Conclusion

Many methods exist to cool the body, primarily evaporative and conductive methods. From the literature presented current evidence strongly supports the use of ice water immersion. In triangulating the data obtained from this literature review although ice water immersion is the most effective, the practicality and logistics of this cooling method in the field environment is highlighted as an issue. The window of opportunity to provide immediate cooling post collapse is narrow and must be done with a modality that has sufficient cooling potential. Soldiers need to be trained in simple cooling methods that are logistically possible in the field such as fanning, removing clothing, dousing in water and where possible the 'Taco method.' If they are immediately evacuated to a medical centre where ice water immersion can commence their chances of survival are increased. Future research should focus on well designed prospective studies that examine the effect of ice water immersion on patient outcomes as well as studies to examine cooling methods that are practical and available in the field environment.

Conflict of Interest

I Rachel L. McKenzie declare there are no potential competing interests regarding this article.

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