

Rethinking Heat Injury in the SOF Multipurpose Canine: A Critical Review

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ABSTRACT

Heat injury is a significant concern of the Special Operations Forces Multipurpose Canine (SOF MPC). The unique athletic abilities and working environment of the SOF MPC differ from that of companion dogs or even conventional military working dogs. This should be considered in the prevention, diagnosis, and treatment of heat injury of the SOF MPC.

A critical review of the literature on canine heat injury as it pertains to working dogs demonstrates limited scientific evidence on best practices for immediate clinical management of heat injury in SOF MPCs. A majority of management guidelines for heat injury in veterinary reference books and journals are based on review articles or professional opinion of the author vs. evidence from original research. In addition, guidelines are written primarily for companion animal populations vs. SOF MPCs and focus on measures to be undertaken in a clinical setting vs. point of injury. The phenomenon of “circular referencing” is also prevalent in the heat injury literature. Current guidelines supported by review articles and textbooks often provide no citation or cite other review articles for clinical standards such as normal temperature ranges, treatment methods, and recurrence of heat injury. This “circular referencing” phenomenon misrepresents anecdotal evidence and professional opinion as scientifically validated, reinforcing concepts and recommendations that are not truly supported by the evidence.

Further study is needed to fully understand heat injury in SOF MPCs and how this applies to prevention, diagnosis and treatment guidelines. In order to provide SOF canine programs with best clinical advice and care, SOF Veterinarians must make clinical judgments based on evaluation of the most accurate and valid information possible. Clinical guidelines are fluid and should be reviewed regularly for relevance to the defined population in question. Clinical Guidelines should also be utilized as guiding principles in conjunction with clinical judgment vs. dictate a clinical protocol. SOF veterinarians as the veterinary support asset to SOF MPC programs should be clinically competent as well as versed in evidence based medicine practices to provide the cutting

edge clinical support that is required to keep SOF MPCs operating in modern warfare environments.

Background

Special Operations Forces Multipurpose Canines (SOF MPC) present unique clinical challenges and may be at increased risk for exertional heat injury due to the intense physical nature of work, harsh working environment, wear of a tactical vest, and extensive work in muzzle. SOF MPCs are selected for extremely high drive and athletic ability. While the selection criteria for SOF MPCs may be protective against heat injury to some degree, the reality of the operational environment pushes the physiologic limits of these elite canine athletes potentially putting them at greater risk than companion animal or conventional Military Working Dog. The greatest challenge to effective prevention, diagnosis, and treatment of SOF MPCs is the understanding of the physiologic limits of this special weapon system.

The available literature is limited to clinical treatment of heat injury in a hospital setting primarily in a companion animal population. However, key lifesaving care must begin immediately for heat injury, long before the dog arrives at a veterinary facility. In order to extend the operational range of the SOF MPC it is essential that the SOF Veterinarian understand the unique operational environment, the occupational hazards and the physiologic limits of the SOF MPC and critically evaluate the available evidence to inform vs. dictate management and care. This approach is similar to the way combat casualty data from the current conflicts drastically changed treatment protocols for battlefield injuries, and may lead to similar improvements in care and management of the generalized population of working dogs.

A Structured Approach to Review of the Literature

Critical review of the literature is an important aspect of clinical medicine that is often overlooked. The overarching goal of the critical review is to synthesize the available

information and use the best available information in your clinical approach. The methodology that was utilized for this publication can be applied to a variety of clinical questions and includes four steps: 1) Formulate a question. This is often derived from clinical observation. 2) Find the best evidence to answer your question. A successful strategy for finding useful information depends as much on how you search as well as where you search 3) Critically evaluate the available evidence. All evidence is not created equal so each article should be evaluated for validity and relevance to your question. 4) Synthesize your results and make your clinical decision. Use your results to inform, not dictate your clinical approach.¹

The literature was evaluated to answer three clinical questions essential to prevention, diagnosis and management of heat injury in SOF MPCs at the point of injury, and aid in decisions for return to duty and deployment.

1) What are normal and abnormal temperature ranges for athletic dogs undergoing strenuous exercise? 2) What are best practices or contraindications for methods of cooling? 3) What is the risk for recurrence of heat injury in dogs with previous heat injury?

Pubmed, CAB Abstracts, Medline, and Veterinary Information Network were searched to answer the three clinical questions posed in this critical review. There was no restriction placed on the date of publication range. Keywords searched were heat stroke, heatstroke, heat injury, heat exhaustion, hyperthermia, exertion, heat prostration, overheating, collapse, canine, dog, working dog, military working dog, police dog, and canine athlete. A supplemental search conducted for articles on human heat injury treatment included the previous keywords and human, athlete, Soldier, Sailor, Airman, Marine, recruit, service member, military, and military trainee. Articles on canine original research were evaluated for inclusion in the review. Non-canine animal models were excluded. Only referenced and peer reviewed articles were considered for inclusion and whenever possible citations were traced back to the original source article.

Literature that met the inclusion criteria were categorized according to a hierarchy described previously in the veterinary literature^{2,3} in which grade I evidence is considered the highest quality and grade IV the lowest quality based on study design (Figure 1). This method is very similar to methods described in the literature for human medicine, but with modifications that allow for categories outside of research on human subjects. Specifically, it accounts for research performed on animals that have been experimentally inflicted with a disease or condition, the fact that randomized, controlled clinical trials are rare in veterinary medicine compared to human medicine, and that veterinary medicine must account for multiple species of patients.

Figure 1 Method of critical review of evidence in the veterinary literature

Grade I: Evidence obtained from one or more properly designed, randomized controlled clinical trials performed in clinical patients of the target species.

Grade II: Evidence obtained from properly designed, randomized, controlled studies performed using animals of the target species with spontaneous disease in a laboratory or animal colony setting.

Grade III: Evidence obtained from appropriately controlled studies without randomization, appropriately designed cohort or case control studies, studies using acceptable models of disease or simulation in the target species, case series or dramatic results from uncontrolled studies.

Grade IV: Evidence obtained from studies conducted in other species, reports of expert committees, descriptive studies, case reports, pathophysiological justification, and opinions of recognized experts on the basis of their clinical experience.

Note: Based on Roudebush et al. 2004. The majority of evidence on heat stroke in canines is Grade III and Grade IV.

While the SOF Veterinarian may find review articles and textbooks helpful in providing readily accessible, detailed information on management of certain conditions, it is important to remember that they are not a source of original information and would not typically be included in a critical review of the scientific literature. Thus, a large amount of material in some review articles and reference books may be based on the clinical experience and opinion of the author, vs. sourcing from original research. To illustrate this point, the question was asked, “How well do clinical guidelines in the review and reference literature reflect the evidence?” An extensive literature search also produced six review articles that were not systematic reviews or meta-analyses, to answer this question. An additional five veterinary reference books thought to be representative, but not all-inclusive of available books, were surveyed for this comparison. These reviews and reference books were reviewed for content regarding canine heat injury to compare them to the evidence in original research. The articles were grouped and evaluated based on relevance to the three clinical questions posed in this critical review.

Results

A total of 14 articles of original research were found that met the inclusion criteria and provided information to answer our three clinical questions. Original research that met the inclusion criteria produced seven experimental studies on heatstroke in dogs with the most recent in 1993,⁴⁻¹⁰ two retrospective case studies,¹¹⁻¹² one case report,¹³ and four experimental studies on changes in body temperature during exercise of working Greyhounds and Labrador Retrievers.¹⁴⁻¹⁷ In the last three decades there

have been multiple review articles¹⁸⁻²³ and in the last decade at least five veterinary textbooks with sections on heat injury.²⁴⁻²⁹ All of the non-retrospective studies on treatment of heat stroke were published between 1977 and 1999, and all used experimentally-induced canine models of heat stroke for treatment or characterization of human heat injury. In accordance with the grading scheme used in our analysis, by nature of study design, all of the evidence was designated as grade III, with the exception of the case report, which was grade IV.

To answer the question “What are normal and abnormal temperature ranges for athletic dogs undergoing strenuous exercise?” the following information was extracted and analyzed. Four experimental studies have demonstrated the body temperature of sporting, racing, and detection dogs to reach between 104° and 108 °F during strenuous exercise with no adverse effects.¹⁴⁻¹⁷ No literature was found that specifically addressed this topic in military working dogs.

To answer the question “What are best practices or contraindications for methods of cooling?” the following information was extracted and analyzed. A 1980 study in experimentally induced heat stroke in dogs demonstrated that cooling by immersion in water temperatures between 33.8–60.8° F (1–16° C) (ice or cold water) had significantly faster cooling times compared to dogs cooled with water temperatures over 64.4° F (18° C) (cool water).⁷ In that study, dogs cooled in ice water demonstrated intense shivering, but cooled down as fast or faster than dogs cooled in water of temperatures from 59° F (15° C) or higher. Their results suggest that the shivering did not significantly inhibit cooling, and that ice water or cold water provided the fastest rate of cooling. The authors also concluded that cold water was a readily available method of cooling that did not cause shivering and was as effective as ice water for cooling. Two dogs in this study, which were already comatose at the initiation of cooling died shortly after immersion in ice water bath, compared to none of the dogs cooled in cold or cool water. However, the authors did not report cooling method vs. survival in their study so no causal relationship between cooling method and outcome could be concluded. This study also demonstrated significantly slower cooling times with all methods of cooling in dogs that were already comatose at initiation of cooling compared to conscious dogs.

One study in 1979 demonstrated that peritoneal lavage produced rapid rates of cooling in dogs,⁸ but a subsequent study in 1993 demonstrated that it was no more effective than evaporative cooling with tap water and fans.⁵

A 1978 study demonstrated that peritoneal lavage with fluids at 68° F (20° C) had faster cooling rates in dogs

with experimentally induced heat stroked dogs than ice slush applied to the skin surface or passive air cooling.⁹ However, a subsequent study in 1993 compared iced peritoneal lavage 42° F (6° C) to evaporative cooling with sprayed water and fanning. This study demonstrated that the evaporative cooling method had significantly faster cooling times than iced peritoneal lavage alone, and had higher survival at 48 hours post injury.⁵ A similar study in 1985 showed that iced gastric lavage cooled dogs with experimentally induced heat stroke dogs at rates comparable to external cooling techniques, and five to six times faster than controls that were allowed to cool with no active cooling methods.⁶

A 1986 study demonstrated that high-frequency jet ventilated cooling was faster than passive cooling, but slower than previously reported rates for gastric and peritoneal lavage.⁴

Two retrospective studies did not report pre-hospital cooling methods, but both studies demonstrated higher survival outcome in dogs with heat stroke that were cooled by their owners prior to presentation to veterinary care compared to dogs that were not cooled by their owners.¹¹⁻¹² In addition, one of the studies found that dogs that received veterinary treatment in less than 90 minutes following initial injury had better outcome than dogs who presented greater than 90 minutes following injury.¹¹ The other retrospective study showed worse outcome in canine patients who were hypothermic on presentation. However this study did not take into account duration from injury to veterinary care (i.e., delayed transport times), or report association with the reason for hypothermia to the outcome.

Our search revealed no articles that met our inclusion criteria to address pre-hospital cooling methods in dogs with heat injury.

No articles were found that met the inclusion criteria addressing the question “What is the risk for recurrence of heat injury in dogs with previous heat injury?”

Analysis and Implication for Clinical Guidelines

Review of the literature revealed sparse scientific evidence to answer two of the three clinical questions evaluated in this critical review. There was a moderate amount of grade III evidence for one of the questions (normal and abnormal temperatures during exercise), the quality of which may be underestimated by most grading methods. The fact that results were repeated in four independent studies by different research groups lends additional credibility to this evidence. The scarcity of clinical trials in veterinary medicine results in much of the evidence residing in categories of grade III or IV, considered low quality evidence.

This situation was evident with the evidence regarding canine heat injury. All of the evidence from original research was classified as grade III by the method used in this study for meeting one of two criteria; 1) Non-randomized studies conducted on acceptable models of animal disease (experimentally-induced heatstroke or hyperthermia) and 2) retrospective cohort studies.

Despite the lack of scientific evidence, many veterinary review articles and textbooks outline emergency treatment and long-term management of dogs with heat injury often with no citations. Because they were largely written without valid citations, these reviews and textbooks are considered grade IV evidence (“expert opinion”). The literature that does include citations primarily references other review articles (i.e., grade IV evidence citing grade IV evidence). When experimental or retrospective studies were cited, tracebacks of the references usually reveal that the cited information was taken from a discussion or introduction section of the cited study, instead of scientifically validated source data. This type of “circular referencing” has led to widely accepted treatment recommendations that have never actually undergone validation with critical scientific review. However limited, the grade III scientific evidence on these three questions fails to support, and in some cases contradicts current grade IV guidelines in veterinary review articles and reference textbooks.

Of the available review literature, a majority is written from the perspective of the university-based veterinarian focused on a patient population of companion dogs and is not directly applicable to pre-hospital treatment guidelines needed for SOF MPC care. Two review articles that included short segments on heat injury were written specifically for human practitioners faced with providing emergency care to working dogs in a combat environment.²²⁻²³ Considering the lack of evidence in the literature regarding working dog medicine and physiology, these articles used largely uncited information and relied on the authors’ extensive practical experience with working dogs. While the weaknesses in the evidence outweigh the strengths when it comes to the available literature, evaluation of the clinical questions in this review brings to question previously accepted conventions, identifies what we don’t know and highlights questions for further exploration.

Re-defining “Normal” and “Abnormal” Temperatures

The first question that was evaluated in this review was “What are normal and abnormal temperature ranges for athletic dogs undergoing strenuous exercise?” Four grade III studies were consistent in their findings that working dogs may demonstrate rectal or core temperatures

between 104° and 108 °F without adverse effects.¹⁴⁻¹⁷ Among all of the review articles and textbooks we examined, only one of these acknowledged that an elevated temperature might be normal after exercise.²² One study demonstrated survival of dogs up to seven days after whole-body heating to 107.6 (42° C) for 60 minutes,¹⁰ and another demonstrated a 20% (3/15) survival rate of dogs 18 hours after heating up to 110 °F (43.5 °C), with no subsequent active cooling.⁷ These results demonstrate that heat injury cannot be defined by body temperature value alone, and that other factors are involved in whether an individual dog reacts adversely to specific increases in body temperature.

Various texts and review articles define different levels of heat injury as a rectal temperature exceeding anywhere from 104–110 °F (40–43.3 °C). Despite the available evidence, our survey of related textbooks and review articles demonstrated that in many cases the source for the temperature reference ranges is not cited, or that the authors cited other grade IV review articles or uncited statements in veterinary textbooks as sources for the original information.

The temperature of a healthy dog might be different with the dog at rest, in an excited or agitated state, or after exertion during normal work. The military veterinarian is often presented with a working dog that is not in a resting, relaxed state, so the traditional definition of “normal” body temperature might not directly apply. While no studies were found that measured temperature ranges after strenuous exercise for Belgian Malinois, Belgian Shepherd, Dutch Shepherd, or German Shepherd Dogs, breeds commonly used in SOF, it is likely that their rectal and core temperatures during exercise would be similar to working Greyhounds and Labrador Retrievers described in previous studies.¹⁴⁻¹⁷

It is difficult to determine critical ranges from standard, referral clinic-based retrospective studies since temperatures are not generally obtained or recorded prior to presentation to the veterinarian. Delayed transport times and pre-hospital cooling measures will likely lower the body temperature before temperature is recorded.

To obtain a truly representative study, temperatures should be obtained at the point of injury, when the dog first shows clinical signs of heat injury. This method would provide more accurate measures on which to compare outcome. A digital thermometer should be included in canine individual first-aid kits (C-IFAK), and handlers should be instructed on the importance of obtaining rectal temperatures in these cases. Alternatively, an internal core temperature sensor may provide a less intrusive means of monitoring temperature during short-duration training or operations (Figure 2).^{14,a}

Figure 2 Internal temperature sensors provide a non-intrusive method of monitoring the temperature of SOF MPCs dogs during operations and training in hot weather



Taking into consideration that normal working temperatures may far exceed what is considered “normal” in resting, or sedentary dogs, the SOF veterinarian should work closely with their respective canine units to establish trends in normal resting and working temperatures for the dogs in their care. Additionally, since no absolute value has been determined to be a consistent predictor of heat injury or degree of severity, when providing training or written materials, the SOF veterinarian should refrain from using specific temperature values as absolute indicators of heat injury, and teach handlers to take the whole dog into consideration, including performance, attitude, and other clinical signs along with temperature. The SOF veterinarian must consider this along with the circumstances and immediate history, as well as the dog’s attitude and appearance at the time of exam, before assuming that an elevated temperature is indicative of pathology. In short: treat the dog, not the thermometer reading.

Question: “What are normal and abnormal temperature ranges for athletic dogs undergoing strenuous exercise?”

Conclusion: There is repeated grade III evidence that working dogs may reach rectal or core temperatures between 104°–108° during strenuous exercise without adverse effects. The majority of review articles and textbooks do not account for these findings.

Best practices in rapid cooling: The use of cold water or ice bath immersion

The thought that cold water or ice bath immersion for treatment of heat injury in dogs is detrimental to outcome has never been scientifically validated; however, many veterinary textbooks and review articles adamantly state

that cold or ice water cooling is contraindicated,^{20-23,26,29} some printed in bold font, all capital letters, or italics for special emphasis. Two textbooks with sections written by the same author state “Immersion in ice baths, or cold water is absolutely contraindicated, as cold water immersion causes peripheral vasoconstriction and prevents vasodilation, one of the animal’s primary methods of cooling.”^{26,29} Our review found no evidence from original research that supports the assertion that cold or ice water cooling is detrimental to survival or outcome, causes disseminated intravascular coagulopathy (DIC), slows down or prevents cooling, or is otherwise associated with poor outcome. Despite this, there is an abundance of grade IV evidence from uncited textbooks and review articles, classified as grade IV for meeting the criteria of “expert opinion,” that caution against the use of cold or ice water for cooling for these reasons.

Cold water or ice bath immersion will likely produce vasoconstriction, and has been shown to cause shivering in dogs in an experimental study of cooling methods.⁷ Although we did not include non-canine studies in this review, it is worth noting that vasoconstriction and shunting of heat to the core during surface cooling has been demonstrated in studies of equine and bovine species, but also demonstrated no deleterious effects or inhibition to cooling.³⁰⁻³¹ In the equine, skin vasoconstriction as a result of repeated intermittent application of cold water (42.8 °F/6 °C) appeared to have a beneficial effect on cooling. The authors described an alternating warming and cooling of pulmonary artery temperature as a result of vasoconstriction to be instrumental in extracting heat from the muscles and transferring it to the body surface.³⁰ In addition to this type of physiologic response, the effects of conduction and convection from cold or ice water immersion may well overcome any inhibition of cooling from vasoconstriction or shivering. Since the equine and bovine have the ability to sweat, unlike the canine, response of the canine may be different and warrants further study.

Metadata analysis comparing cooling methods in humans with hyperthermia showed the most rapid cooling rates resulted from ice water or cold water immersion compared to cool or tepid water, application of wet towels, or sprayed water and continual fanning. In addition, that analysis found no adverse effects associated with cold or ice water immersion method.³² Ice water immersion with circulating water is considered the superior whole-body cooling treatment for exercise-induced hyperthermia in humans.³²⁻³⁵

Gastric or peritoneal lavage were also evaluated in this review and found to be impractical methods for a field environment, as was high-frequency jet ventilation cooling,^{4-6,9} and since they show no obvious benefit to

outcome compared to less invasive methods we do not recommend these methods in favor of traditional and more practical external methods of cooling.

In reality, canine handlers and medics in an operational environment will likely not have the luxury of choosing between multiple methods of cooling. They will have to rely on sparse resources including natural water sources such as creeks and drainage ditches, personal water supplies, shaded areas, and fanning by hand. Even in a garrison-based field-training environment, they will likely have limited immediate sources of water or ice, relying on water bottles and air-conditioned vehicles for initial cooling. Complicated cooling regimens fill textbooks and first aid manuals, recommending cool, but not cold water, instructing to spray the dog with water, fan the patient, and to place alcohol on the paw pads, when the key to field treatment is simply to cool the dog down as fast as possible using whatever methods are available. Veterinarians should avoid unnecessary complication of treatment guidelines when training handlers and other non-veterinary personnel. Unless there are specific and scientifically validated species differences to warrant otherwise, training for management of canine emergencies should follow as closely to the human treatment guidelines as possible to avoid confusion from “two sets of rules.”

Question: What are best practices or contraindications for methods of cooling?

Conclusion: There is some grade III evidence that iced or cold water-cooling provides the fastest cooling rate compared to use of cool water. There is limited grade III evidence that spraying with water and use of fans is just as effective at cooling as more invasive methods like peritoneal lavage. There is duplicated grade III evidence that cooling initiated before arrival to veterinary care is associated with increased survival. We found no literature meeting our inclusion criteria with evidence supporting the concept that cold or ice water cooling slows cooling or is detrimental to outcome of dogs with heatstroke. These findings fail to support, and possibly contradict the abundant grade IV evidence in review articles and veterinary textbooks that caution against cold or ice water cooling.

Are dogs that have incurred heat injury more susceptible to heat injury in the future?

It has long been thought that once a dog incurs heat injury, it is at risk for heatstroke in the future. To our knowledge, association of prior heat injury and recurrence in dogs has not been studied. Neither of the retrospective studies in canine heatstroke examined prior history of heat injury as a predisposing factor.^{11,12} However, if the circumstances, which led to a previous

Figure 3 *The key to life-saving treatment for canine heat injury is immediate cooling using whatever resources are available*



incidence of heat injury have not changed, and the dog is expected to work in the same environmental conditions, then it stands to reason that heat injury would be likely to occur again.

There is evidence in human medicine that individuals incurring heatstroke may show signs of heat intolerance for 30 days to several months after initial injury.³⁶⁻³⁹ In humans, a heat tolerance test is recommended for Soldiers with history of heat injury to determine suitability for full return to duty.³⁶⁻³⁹ We found no description of a standardized heat tolerance test for working dogs in the literature. The SOF veterinarian should not automatically restrict an individual dog's ability to deploy, or judge their suitability for work based only on prior history of heat injury. The most reliable method of determining a dog's susceptibility to heat injury or suitability for deployment may be to evaluate the dog under conditions as close to the deployed situation as possible, allowing for adequate time to acclimate and increase physical conditioning before making a final determination.

Question: What is the risk for recurrence of heat injury in dogs with previous heat injury?

Conclusion: There were no articles meeting our inclusion criteria indicating dogs with history of heat injury are more susceptible to heat injury in the future. Review articles occasionally provide uncited statements that dogs with history of heat injury are more susceptible in the future.

Conclusion

The unique athletic qualities and working environment of the SOF MPC should be considered in the prevention,

diagnosis, and treatment of heat injury in these dogs. Guidelines for prevention and treatment of heat injury in SOF dogs should take into consideration that they are often exceptional canine athletes compared to most companion dogs, and are not working in ideal environments. Prevention and treatment options may be limited at the point of injury; however, this is possibly where the most rapid and aggressive treatment is needed. SOF veterinarians should carefully review the literature and evidence themselves vs. propagate information that has not been scientifically verified when training canine handlers and other medical personnel. This information should be combined with clinical experience and judgment when dealing with heat injury in the SOF MPC patient. The SOF veterinarian cannot rely solely on their university-based training and civilian veterinary literature when advising SOF MPC programs on topics of environmental extremes, and must also consider the experience of SOF medical personnel treating the dog in the field, the canine handler working and assessing the dog's performance, and assessment of individual dogs in all aspects of heat injury prevention and management. In addition, further research is needed on the response of canine athletes such as the SOF canine to physical exertion in environmental extremes common of their working environment.

Note

- a. CorTemp Core Temperature Monitoring System HQInc, Palmetto, FL.

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