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Body Temperature Responses during Phases of Work in Human Remains Detection Dogs Undergoing a Simulated Deployment

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SIMPLE SUMMARY

Working dogs are frequently transported via crates in vehicles to various deployment scenarios. Body temperature increase associated with exercise is common but has not been assessed throughout the entire work cycle for dogs during a deployment scenario. We measured continuous temperature changes for dogs throughout an entire day of search operations while in each stage of the work cycle including waiting to work, active work, and post-work recovery. We found that dogs did not increase in temperature while anticipating work but did increase

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during the period of active work. Additionally, when dogs were returned to vehicles for crate and rest during the post-work recovery period, body temperatures continued to increase. We suggest that post-work recovery in the vehicle should be further investigated to better manage dogs through continuing search operations.

ABSTRACT

Body temperature responses were recorded during phases of work (waiting to work in close proximity to search site, active work in a search site, and post-work recovery crated in vehicle) in human remains detection dogs during search training. State or federally certified human remains detection dogs (n = 8) completed eight iterations of searching, rotating through six different types of search environments to detect numerous scent sources including partial and complete, buried, hidden, or fully visible human remains. Internal temperature (Tgi) of the body was measured continuously using an ingestible thermistor in the gastrointestinal tract. Mean total phase times were: waiting to work: 9.17 minutes (± 2.27); active work: 8:58 minutes (± 2:49); and post work recovery: 24:04 minutes (± 10.59). Tgi was impacted by phase of work ($P < 0.001$) with a small increase during active work, with mean peak temperature 39.4 °C (± 0.34 ºC) during that period. Tgi continued to increase for a mean of 7:37 (± 6:04) minutes into the post-work recovery phase in the handler's vehicle with a mean peak Tgi of 39.66 °C (± 0.41 ºC). No significant increase in temperature was measured during the waiting to work phase, suggesting anticipation of work did not appear to contribute to overall body temperature increase during the waiting to work recovery cycle. Continued increase of gastrointestinal body temperature several minutes after cessation of exercise indicates that risk of heat injury does not immediately stop when the dog stops exercising, although none of the dogs in this study reached clinically concerning body temperatures or displayed any behavioral signs suggestive of pending heat

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injury. More work is needed to better understand the impact of vehicle crating on post-work recovery temperatures in dogs.

INTRODUCTION

Working dogs and other canine athletes often follow a cycle of waiting or staging to work, active work, and post-work recovery. During actual search deployments, dogs will often stage while waiting to work in a vehicle or crate near the search site. Similarly, they are often returned to this or similar environment immediately following active work. Little is known about the response of body temperature throughout these phases continually. Body temperature is a particularly important physiologic parameter to monitor during these cycles, combined with observation of potential changes in behavior, to both mitigate life-threatening heat injury as well as safely maximize the duration of work the canine can perform. Multiple studies have characterized body temperature changes of dogs during exercise and during short recovery periods following exercise [1–5]. However, body temperature alone, collected at a single time point, fails to accurately predict or define heat injury. Numerous studies have shown conditioned dogs reaching temperatures of over 41 °C, and as high as over 42 °C during exercise, with no adverse effects [3,6–8]. Thus, other ways of looking at body temperature other than peak temperature as a measure of thermal status in dogs should be investigated. In addition, studies on dogs in controlled laboratory settings may not accurately represent physiological responses of trained working dogs under field conditions which typically includes transportation and crating within a vehicle.

Many studies have investigated changes in body temperature of various types of working and sporting dogs during active exercise [1–6,9–12]. Diviero et al (2016) and Rovira et al (2008) specifically studied changes in search and rescue (SAR) dogs in cold (approximately -

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10° C) and more moderate (approximately 21 °C) temperatures, respectively. However, few data are available regarding the impact of deployment conditions on the temperature of working dogs throughout a day of work or training in the field from waiting or staging to work, active work, and in post-work recovery while crated in a vehicle.

In this study, our objective was to evaluate the hypothesis that body temperature responses in dogs would follow distinct and thus predictable patterns throughout the different phases of work, using a waiting-to-work, active work, and post-work recovery cycle, with measurements obtained in the typical environment for that phase, whether in a crate, the active search site, or recovering in the handler's vehicle. Furthermore, we hypothesized that dogs would have a rise in temperature associated with anticipation of work with potential continued increase throughout traditional work cycles and the post-work recovery phase. Knowledge of these patterns could be beneficial in understanding expected body temperature changes in dogs during work, help mitigate adverse effects such as heat injury, and better understand patterns of thermoregulation in the canine athlete.

MATERIALS AND METHODS

Animals & Diet

Ten urban search and rescue (USAR) dogs (BW = 26.53 ± 5.54 kg; BCS = 4.5 ± 0.5) that were trained and or certified to a national testing standard in human remains detection were initially recruited for the study. Participants were standardized to a commercially available diet (Canidae® Pure) for 30 days prior to the study. Canines had *ad libitum* access to water throughout the experimental period and were examined by a licensed veterinarian immediately prior to inclusion of the study. Upon veterinary exam, one canine displayed excessive aggression

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and was removed from the study. Another canine was also removed from the analysis due to a suspected undiagnosed metabolic disorder. Thus, the results and discussion presented are for a total of eight dogs. Care and handling of animals used in this study was approved by Southern Illinois University Animal Care and Use Committee, Animal Use Protocol 16-037. Physical characteristics for participating dogs are presented in Table 1.

Table 1. Characteristic of human remains detection dogs.

Canine	**Breed**	**Sex[1]**	**Age[2]**	**BW (kg)**	**BCS[3]**
1	Labrador Retriever	FS	5y	23.58	4
2	Golden Retriever	F	1y	19.50	5
3	Pit Bull Mix	MN	4y	24.95	5
4	Belgian Malinois	M	2.5y	30.84	5
5	Belgian Malinois	FS	8y	24.49	5
6	McNab	M	1y	21.77	4
7	German Shepherd	MN	8y	34.93	4
8	German Shepherd	MN	6y	32.20	4.5

[1]Sex: FS = female spayed; F = female intact; MN = male neutered; M = male intact
[2]Age: y = years old
[3]Nestle Purina Body Condition System, scale 1-9

Study Design

Canines were randomly assigned to rotate through six deployment search sites in which whole, or partial human remains in various states of decomposition at a forensic anthropology field laboratory were situated, repeating two of the sites for a total of eight search iterations for each dog. Search site areas ranged from 5,100 ft^2 – 18,800 ft^2 with terrain typical of disaster

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deployments including a grass field, fallen building rubble, a mass casualty scenario, and wide area with trees. Phases of work for each site were defined as: WW = waiting-to-work in staging area with exposure to olfactory, auditory, and limited visual stimuli and the dog crated next to handler; AW = active work off leash within the search site; PWR = post-work recovery crated in the handler's vehicle with no exposure to visual or olfactory stimuli from the search sites. Handler vehicles were typically of those used in the working dog industry as evidenced by the examples provided below (Images 1-4).

Images 1-4. Typical vehicle crating formats for working dogs.

Image 1. Cargo van with dual crate system and removal middle divider.

Photo credit Karen Meadows

Image 2 a & b. Pickup trucks with single crate system in cargo seat

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Photo credit Michael O'Neil and Kathleen Kelsey

Image 3. Pickup truck with camper shell and dual crate system with battery operated mounted fans.

Photo credit Cathy Schiltz

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Image 4. Canine transported during deployment without crate.

Handler vehicles included pick-up trucks with camper shells (2), pick-up trucks with open bed (2), SUV (3), and a minivan (1) as shown in Image 5.

Image 5. Vehicles and crating formats used to simulate deployment conditions for working canines utilized.

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No dogs were exposed to air conditioning and doors and/or windows were opened to maximize air flow in all vehicles except the open-backed pick-up trucks, in which dogs were crated (See Image 5). Because of the small number of vehicles, and variety of vehicles, differences of dogs' body temperature between vehicle types was not evaluated. This phase design was utilized for all sites and was documented for each dog throughout the duration of the study. All dogs completed all sites in a randomized order and then repeated their first two search sites for a total of 8 waiting-working-recovering iterations for each dog. Dog-handler teams worked for 7.5 hours across all sites.

Animal Performance and Sample Collections

Environmental temperature and humidity were recorded hourly (National Oceanic & Atmospheric Administration (NOAA), Carbondale/Murphysboro Southern Illinois Airport, 5.8 miles from study location).

Gastrointestinal body temperature (Tgi) was measured in the gastrointestinal tract utilizing CorTemp ® Ingestible Sensor: 262kHz (HT150002; HQ, Inc.; Palmetto, Florida, USA) and recorded the gastrointestinal temperature in ten second increments. All participants received the sensors approximately 30 minutes prior to initiation of data collection. CorTemp ®

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Ingestible Sensors have been previously utilized for core body temperature studies in canines [1,6,11,13,14]. Sensors were ingested 45 minutes (±15) prior to initiation of the study. CorTemp ® Data recorders were affixed within a medical vest (Medical Pet Shirt International BV, MPS Protective Top Shirt 4 in 1, Netherlands) worn by each dog for the duration of the study.

Baseline temperature was noted as the first temperature reading at the first WW period of the day (one measure per study participant). *Iteration Baseline* temperature was considered the first temperature reading of each WW period (eight measures per study participant). *Peak temperature* was noted as the highest recorded temperature at any point in each complete WW, AW, and PWR cycle (eight measures per study participant). Dogs were allowed to drink water in the Post Work Recovery phase which is known to momentarily drop the temperature recorded by the ingestible thermistor. Thus, body temperature recordings of under 35 °C (95 °F) were excluded from analysis.

Statistical Analysis

Numerical data were assessed for a normal distribution by the Shapiro-Wilk test. Normally distributed numerical data are summarized as mean (± SD)). Non-independent parametric numerical data, comparisons of Tgi in the same dog, were tested by paired t-test. Numerical data for multiple groups, e.g. dogs, work phases, or iterations, were compared by ANOVA of ranks. Correlation between non-parametrically distributed numerical variables were assessed by Spearman's rank correlation coefficient (rho). Proportions were compared by the χ^2 test of association. Statistical analysis was performed using commercially available software (STATA SE, v. 15.1, StataCorp, College Station, TX 77845) with statistical significance established at $P < 0.05$.

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RESULTS

Our dataset yielded 190 complete sets from 192 possible with each set representing one phase (WW, AW, or PWR) of one distinct rotation for one dog. Incomplete datasets resulted from failure of the CorTemp system to capture or report >3 minutes of temperature in one dog, impacting 2 datasets which were excluded from analysis. Mean ambient temperature during the study period was 19.9 °C (± 4.23). Relative humidity was 83.2% (± 0.162) with a mean ambient temperature of 23.3°C for the morning iterations (9am-12:00pm) and afternoon temperatures (approximately 1:00pm-4:45pm) of 15.6 °C. Mean total phase times were: WW: 9.17 (± 2.27) minutes; AW: 8:58 (± 2.49) minutes; and PWR: 24:04 (± 10.59) minutes.

The highest measured Tgi of any dog during the study was 40.6 °C occurring in the post-work recovery phase of the second iteration of the day. Mean peak Tgi of all dogs was 39.66 ° (± 0.40) °C across all iterations and phases of work. Mean increase was 0.66 ° C (± 0.19) from mean iteration baseline of 39.0 °C (± 0.377). Peak Tgi was significantly more likely to occur in the PWR phase than the AW phase ($P < 0.001$).

Tgi was impacted by phase of work with a small but steady increase during active work, with a high temp of 39.4 ° C (± 0.35) during AW and continuing to increase by 0.66 ºC over a span of 7:37 (± 6:04) minutes following cessation of exercise during the post-work recovery phase (Figure 1).

Figure 1. Mean gastrointestinal temperature (Tgi) of human remains detection dogs during post-work recovery.

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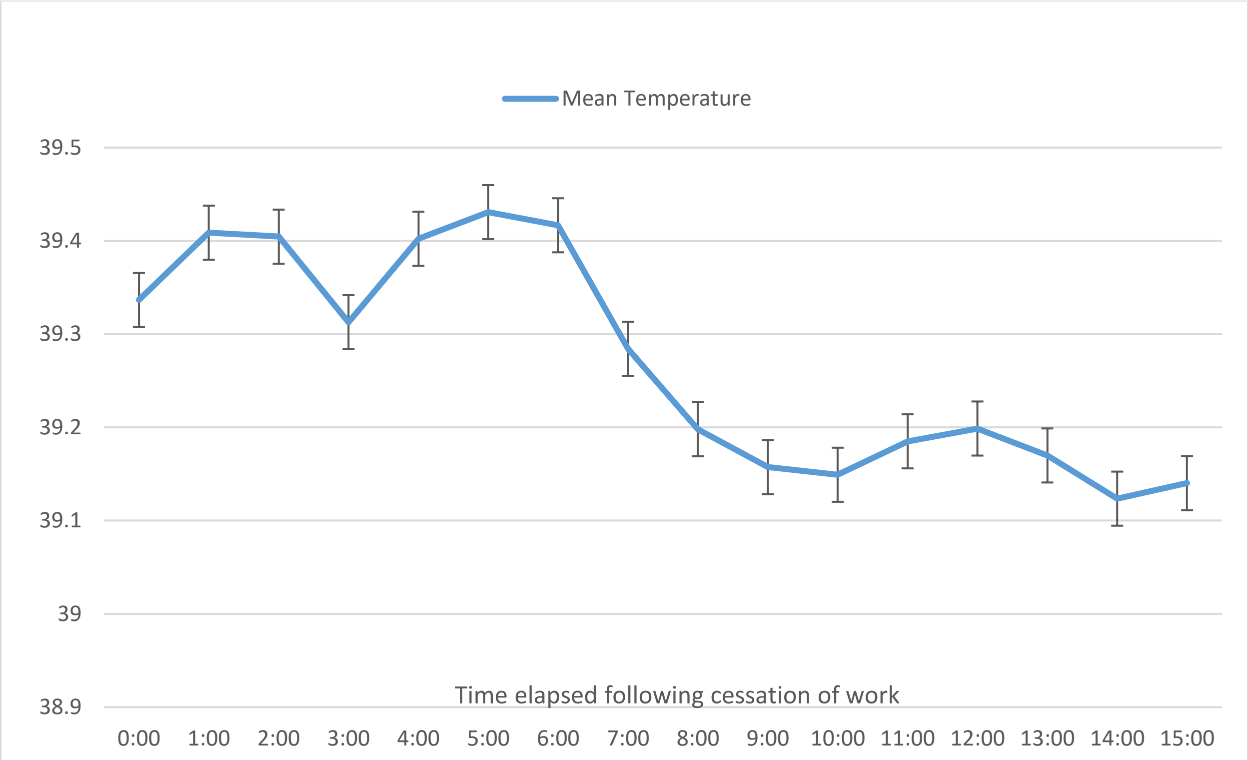

Time spent working was inversely related to the time required to reach peak temperature in the recovery phase (Spearman's rho = -0.517; P< 0.0001). In 54.2% of the iterations, the peak temperature was followed by a rapid but brief drop in measured temperature. No increase in Tgi was measured during the waiting-to-work (WW) phase (P=0.073). Time of day, which was associated with greatly varying environmental temperatures and large drop in temperature as the day progressed, did not impact time or phase when the peak temperature occurred, (P = 0.236).

DISCUSSION

Waiting-to-Work

Unlike previous studies on the effect of anticipation of work [4,10], body temperatures in the dogs did not increase during the waiting-to-work phase despite the fact the dogs were

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exposed to auditory, olfactory, and some visual cues of the working environment. Gillette et al (2011) showed increases in rectal temperature, heart and respiratory rates of Greyhounds in anticipation of a trained exercise event. Dogs that were positioned to watch other dogs continued to show increases in rectal temperature and heart rate, even though they were not participating in the exercise. Diviero et al in a 2016 study on avalanche search dogs, showed an increase in 0.58° C that could be attributed to environment and anticipation stress, measured after helicopter transport and lowering from the helicopter by harness with the handler. This study that showed after significant increases in rectal temperature in anticipation of work, rectal temperatures remained relatively constant with a mean of 39.15 °C throughout their approximately 10-minute search. This may have been affected by the fact that the dogs were working in snow at ambient temperature ranges of between -8.5 °C and -10.4 °C with wind chill temperature of -29 °C. Dogs in the moderate temperature study were noted to reach mean peak of 40.64 °C after 20 minutes of exercise (Gillette 2011).

It is not clear why we did not see similar anticipatory responses in this group of dogs. Differences in training, acclimation to their environment, or other more complex behavioral aspects may have played a role in this difference, and further study on the effect of work anticipation on physiologic parameters is warranted. Dogs that are well acclimated to deployment conditions are likely conditioned to waiting and it is possible that this may have prevented a temperature increase as reported in prior studies [4,10].

Active work

The dogs in our study demonstrated a consistent rise in gastrointestinal temperature during active work, with a mean increase of 0.39° C, which was small in comparison to other

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studies in exercising dogs. The highest temperature of any individual dog during active work reached 40.24 °C. The continued rise in body temperature is consistent with previous studies that measured Ti using the same instrument system [1,3,6,7,11]. However, the Baker and Davis study showed a trend toward temperature plateau during active exercise in dogs when they were in a highly conditioned state, but a continual rise throughout active work when unconditioned. Nazar et al (1992) demonstrated that unconditioned dogs (those that had been restricted from activity for 8 weeks) had a more rapid rise in rectal temperature in response to exercise than they did after they were in a conditioned state, and although their endurance (time to exhaustion) increased by 119% after conditioning, they showed signs of exhaustion at similar rectal temperatures as when activity was restricted. The plateau effect reported in studies of exercising dogs [1,15] was not seen during the active work phase in our study, possibly due to the shorter working times in our study. Also, while it was assessed that this group of dogs was fit for duty, we did not attempt to control or quantify the degree of physical fitness or conditioning regiments between individual dogs, so lack of temperature plateau during active work cannot be adequately assessed here.

Post-Work Recovery

Peak temperature following exercise was significantly more likely to occur in the PWR phase than the AW phase with 95.16 % recorded peaks occurring in the PWR phase several minutes following cessation of exercise (mean 7.37 minutes). Mean peak Tgi was 39.66 °C This is similar to results described by Pellegrino et al (2018), O'Brien (2017) and Rovira et al (2008). Pelligrino et al (2018) demonstrated that rectal temperatures peaked at 40.5 °C five minutes after cessation of sprint exercise in Greyhounds, while temperatures of military working dogs in the

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O'Brien, et al. study continued to rise for 8 to 12 minutes following end of exercise, demonstrating that continued metabolic heat production was greater than cooling by normal thermoregulatory methods (i.e. panting) and passive environmental cooling. Rovira et al (2008) demonstrated that search and rescue dogs peaked at a mean rectal temperature of 40.64 °C and did not show a significant drop in temperature throughout the entire 30-minute recovery period, suggesting that in those dogs, continued metabolic heat production was equal to thermoregulatory and passive environmental cooling combined throughout the recorded post-work recovery phase. Recovery phase housing details are not consistently provided in prior studies and differences in crating, vehicle transport, or return to kennels may contribute to contradictory results.

Surprisingly, there was an inverse relationship between time of active work and time until peak temperature occurred after cessation of exercise. Time in the active work phase reflects the time to complete a search problem and provide a final trained response to alert location of the target odor. The longer a dog took to complete the search problem and alert to target odor, the shorter time until the temperature peaked in the post-work recovery phase and the dog's temperature began to drop with passive cooling in a vehicle crate. Initially this seems counterintuitive, assuming longer duration of work would result in a longer period of continued rise in body temperature after exercise has stopped. However, it may be that the longer length of time to complete the search problem reflects dogs that worked more slowly and methodically in their search behavior, with less overall exertion in this time period.

Limitations of this study include the varying times in the various phases of work. WW: 5.83-21.00 minutes (15.17-minute range difference); AW: 8.33 2.67-16.67 minutes (14-minute range difference); and PWR: 6.00-54.00 minutes (48-minute range difference). These

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differences were allowed so to not interfere with the dogs' training during the search, understanding that some dogs will locate and alert to the target scent more quickly than others. This reflects a common issue with field-based study of working dogs in action, where a controlled laboratory environment is traded for a less controlled, but more realistic working environment. This range of times in the active work phase impacted peak temperature, but surprisingly in the opposite manner of what we expected, with longer active working times being associated with a shorter time to peak temperature in the post-work recovery phase. Despite the range of waiting-to-work times (15.17-minute difference between shorts and longest time), there was no significant impact on body temperature based on time in this phase. In addition, a significant drop in ambient temperature (8.48 °C) occurred from the morning to afternoon iterations, making it difficult to compare body temperature responses to subsequent iterations of work.

Although the phenomenon of continual rise in body temperature following cessation of exercise is well-documented in the scientific literature [2,3,5], its importance is not readily emphasized in veterinary guidelines on prevention of canine heat injury, particularly with regard to vehicle crating following work for dogs. Gastrointestinal temperatures demonstrated by the dogs in our study were relatively low compared to previous studies, with a mean peak of only 39.66 ° ± 0.40 °C at the highest point in any of the three phases of work, although the highest temperature recorded of any of the dogs was 40.6 °C. These data demonstrate that a continual rise in temperature post-work occurs even when body temperatures are barely above reference ranges for clinical hyperthermia. Due to the small number of dogs and vehicles used in this study, we chose not to evaluate the impact of different type of vehicle environments on body temperature changes. It is unknown whether holding the dogs in vehicle crates immediately following

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exercise had an impact on the actual rate of body temperate change during post-work recovery, and whether this would have been different had the dogs returned to outdoor crates or rested on lead with their owners. However, this is common practice during training and actual search deployments and highlights that the risk for potential heat injury does not end abruptly with the cessation of active exercise or work. Further study in the impact of different types of vehicle environments on canine thermoregulation is warranted to help identify those that may facilitate or hinder cooling during post-work recovery.

The addition of our results to the scientific base provides characterization of body temperature responses throughout the phases of waiting-to-work, active work, and post-work recovery over multiple iterations of work typical of deployment conditions. Based on these findings along with previous studies on post-exercise rise in body temperature, we recommend that monitoring of body temperature and behaviors indicative of heat injury should continue after cessation of work until body temperature peaks and begins to decline.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DISCLAIMER

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