Effectiveness of Aluminet® suits on the thermoregulation of canines

by

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Abstract

Thermoregulation is a critical factor for a working canine to be able to function in hot/humid environmental conditions. The purpose of this study was to determine if an Aluminet® Suit would reduce thermal stress imposed on a canine by the environment, through reducing the amount of radiant heat absorbed by the body; thereby, improving the canine's ability to better tolerate the stressors of work and heat. Fourteen working canines participated in a control and three vest/suit conditions while running on a treadmill for 20 minutes at 8 kmh-1 at a 0% grade. The results of this study showed that wearing a Canvas Vest or a Canvas/Aluminet® Vest caused significant ($P \leq 0.05$) increases in Heart Rate from Pre to Post work. There was no change in work intensity across the conditions, but increased Heart Rates Post work in the Canvas Vest and Canvas/Aluminet® Vest conditions initiated innate behavioural responses in the canines. Specifically, the canines attempted to dissipate heat by lying down, to maintain homeostasis. The results showed that wearing a vest/suit made of Canvas or Aluminet®, or a combination there of, had no significant effect on a canine's ability to thermoregulate at 27° ± 0.63°C with 60% ± 3.35 humidity.

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List of Abbreviations

Avg.	Average
CPS	Canine Performance Sciences
°C	Celsius
cm	Centimetres
g	Grams
IR	Infrared Thermal Imaging
kg	Kilogram
kmh-1	Kilometers per Hour
%	Percent
StDev.	Standard Deviation
V	Volts
W	Watts

Chapter I

Introduction

Thermoregulation is crucial to the performance of a canine. Canine thermoregulation involves conduction, convection, radiation, and evaporation to balance heat production and dissipation, so body temperature can be regulated and maintained. This process is influenced by the environment and vests worn by working canines. The vest effects on core temperature needs to be managed while wearing canine working vests to avoid non-productive temperatures that affect a canine's capacity to work. Materials have been created in an attempt to reduce or alleviate the temperature effects vests have on canines, but published research was not found to determine the effectiveness of the vests. The purpose of this study was to determine if an Aluminet® Suit would reduce thermal stress imposed on a canine, by the environment, through reducing the amount of radiant heat absorbed by the body; thereby, improving the canine's ability to better tolerate the stressors of work and heat.

Chapter II

Review of Literature

Specialized working canines can perform jobs in detection, tracking, therapy, service, sled, police, and rescue work. Working canines are not pets, but rather learn and perform tasks that aid and protect humans. Working canines must be able to perform in extreme conditions to help their human handler. Specifically, these canines must be able to move efficiently over various surfaces, terrains and obstacles, operate in various climates, have good posture, balance, stability, agility, coordination, speed, power and flexibility, superior muscular and cardiovascular endurance, and not become fatigued or injured. If the canine becomes fatigued or injured, they become inefficient or unable to perform their specific task and could endanger the safety of their handler or civilians. As a result, thermoregulation is crucial to the performance of a working canine, yet little research has been conducted on canine thermoregulation. Therefore, the scope of this review will include and be supplemented with human thermoregulation literature to help explain canine thermoregulation.

Importance of Thermoregulation

Thermoregulation is the process by which the balance of heat production and heat loss is maintained. Heat is internally generated by metabolic processes and muscular activity and externally gained from the environment. Heat loss can occur as a result of radiation, conduction, convection, and evaporation. Body heat is removed at the body's surface when it is transported to the skin by circulating blood and is released into the environment (Guyton, 2006 and Flournoy et al., 2003). Changes in body temperature are detected by thermoreceptors located throughout the body (i.e. in the skin, mucous membranes, spinal cord and abdominal visceral organs). Stimulation of these thermoreceptors triggers peripheral vasodilation and central vasoconstriction, which sends the heated core blood to the extremities and surface for heat dissipation. The thermoregulatory center in the hypothalamus controls this balance of heat dissipation and heat production to maintain body temperature and homeostasis (Flournoy et al., 2003 and Hemmelgarn and Gannon, 2013). Multiple thermoregulatory mechanisms in the body contribute to heat dissipation to regulate and maintain homeostasis.

Human Temperature and Thermoregulation

In humans, core body temperature is normally maintained at approximately 37°C. Body temperature that reaches above this normal value initiates heat dissipating processes (Guyton, 2000). Body heat is dissipated through conduction, convection, radiation, and evaporation. Conduction is the exchange of heat between two objects when they come into contact (Flournoy et al., 2003). Conduction transfers heat from the body when it comes in contact with a cooler surface. Convection transfers heat to the environment when air or water removes heat from the surface. Air movement, such as a fan can help remove heat as well as natural convection that occurs when the heat from the body surfaces rises causing a natural air flow. Body heat is lost through radiation simply by the body releasing heat into the environment (Johnson et al., 2006). Heat can be absorbed from the environment into the body via radiation and convection when globe temperature and dry ambient temperature exceed skin temperature (Kenney, 2011). Evaporation occurs when fluid changes into a vapor and is released in to the environment (Johnson et al., 2006). Murakami et al. (2000) found heat lost from a standing person, with metabolic heat production of 1.7 Mets, to be 29.0% lost by convection, 38.1% lost by radiation, 24.2% lost by evaporation and 8.7% lost by respiration. These values have not been calculated for canines.

Canine Thermoregulation

Canine thermoregulation involves conduction, convection, radiation, and evaporation to balance heat production and dissipation. Normal canine temperature ranges from 37.5 to 39.2°C (Morgan, 2008), while observed exercising temperatures have been reported reaching above 41°C (Raschke, 2013, Philips et al., 1981; Wagner et al., 1977; Chapman and Baker, 1984). Temperature regulation in canines is crucial for increasing working duration (Young et al., 1959, Kozlowski et al., 1985, and Kruk et al., 1985). In canines, the mechanisms of heat dissipation are the same as humans, but depending on the ambient temperature, vary in degree of effectiveness. Greater than 70% of the total canine body heat is lost due to radiation and convection when ambient temperatures are below skin temperatures (Lewis, 1976). Canines lie down on their abdomen, on cool surfaces, to transfer heat via conduction (Kruk et al., 1985 and Flournoy et al., 2003). At ambient temperatures below 32°C, convection, conduction, and radiation contribute the greatest to normothermia, but as the environmental temperature reaches body temperature, evaporation becomes the most effective way for a canine to dissipate heat (Flournoy et al., 2003).

Both humans and canines dissipate heat through evaporation at temperatures above skin temperature; however, the methods location of evaporation are quite different. In humans, cooling through evaporation occurs through perspiration. In canines, their footpads will produce perspiration, but is an ineffective way to cool via evaporation due to the small surface area and because canines stand on their feet. Evaporative cooling through perspiration is not as effective in canines as in humans, so as temperatures reach above 32°C, panting becomes the most important means of evaporation (Johnson et al., 2006). Panting regulates canine body temperature by increasing the evaporation of water from the respiratory tract (Crawford, 1962 and Young et al., 1959). Panting brings large quantities of air in contact with the mucosal surfaces of the nose and mouth (Johnson et al., 2006), as the nasal turbinates provide a large surface area for evaporation to occur from the moist membranes (Flournoy et al., 2003). Sanders et al. (1977) and Hales and Dampney (1975), through the use of microspheres, found a five-fold and a 16 fold increase respectively, in blood flow to the tongue during exercising. Changes in blood flow to the skin, nasal mucosa, and turbinates, tongue, skeletal muscle, and other areas in the body illustrate the redistribution of cardiac output to regulate the effects of heat stress (Hales, 1973). Large amounts of blood flow from the common carotid artery to the tongue allows for more heat to be dissipated through evaporation (Baker et al., 1982). Heat and exercise increase panting rates in canines (Chapman and Baker, 1984 and Hales and Dampney, 1975) as they must effectively dissipate heat to continue to work.

Canines exercising at high work intensities (i.e. exhaustive treadmill running at or above 12 degrees of inclination at 5.8 kmh-1) dissipate 60% of their heat through evaporation, while the other 40% is lost by radiation and convection. A rise in rectal temperature, due to work, increases panting and correlates with performance capacity (Young et al., 1959). Thermoregulating while working is imperative to maintaining performance. It has been confirmed that maintaining lower body temperatures increase a canine's work duration (Kozlowski et al., 1985 and Kruk et al. 1985). Young et al. (1959) demonstrated that body temperature rose with running time during workloads in excess of 12 degrees of inclination, and that performance was dependent on the body temperature in their 28 all-out endurance tests.

Previous literature has demonstrated that work will increase body temperature, and high body temperatures affect work performance, so canines must be able to effectively dissipate heat to continue to work. When a canine is no longer able to dissipate more heat than it produces, it will overheat and eventually cease to work. Kruk et al. (1985) investigated the effects of cooling a canine during exhaustive treadmill exercises at 5.8 kmh-1, 21% slope, at 22°C. To achieve this a special canvas jacket was placed on the trunk of the canine and filled it with 2 kg of ice. The results indicated that a significant increase in exercise performance was attained at lower body temperatures. The authors concluded that the lower body temperatures resulted from the combination of cooling of the trunk skin, which subsequently cooled the blood flowing through this area. Furthermore, additional contribution to the noted decrease in body temperature was attributed to a decrease in metabolic heat production due to a reduction in respiratory muscle work (Kruk et al. 1985). Kozlowski et al. (1985) investigated canines running on treadmills at 4.3 to 5.8 kmh-1 at a 21% grade until exhaustion, and found that without external cooling, deep body temperatures reached up to 41.8°C and working muscle temperatures up to 43°C. Kozlowski et al. (1985), also utilizing a special canvas jacket filled with 2kg of crushed ice, placed on the trunk of the canine for external cooling, lowered deep body and muscle temperatures by 1.1 and 1.2°C, to 39.4°C and 39.7°C, respectively. It was determined that external cooling lowered deep body and muscle temperatures and increased exercise duration by ~45%, indicating that a lower working body temperature enhances working ability and duration (Kozlowski et al. 1985).

Working Canine Vests

Working canines wear vests for a variety of reasons. Canines working in military, police, search and rescue, therapy, or service operations wear vests every day. Originally, military working canines worked in relatively small local areas and just needed a leash and collar. Today, vests are worn so they can easily be attached to a handler to be transported, hoisted, carried, or even parachuted with a handler, around large areas or into tactical theaters of operation. Their vest could be used to provide armor protection in combat zones, areas of hostilities, and law enforcement operations or it could allow the canine to carry supplies or equipment to help the canine team (Cigard and Gonzalez, 2009 and Gonzalez and Cigard, 2010). Service or therapy canines wear vests to identify their job or allow the attachment of a special harness that has adaptive equipment to assist the human or to alert the public that these canines are "working". Wearing a vest is a necessary piece of equipment, but adds weight and potentially heat to the canine.

Military or law enforcement canines wear vests for protection. Ballistic vests are designed to provide protection for canines during police or military operations. Ballistic vests are typically made from many layers of Kevlar and are placed inside a fabric shell that is usually made from a polyester/cotton blend or nylon. Raschke et al. (2013) studied the effects of ballistic vests on canine core temperature. These researchers measured the effects of three ballistic vest designs during an obstacle course run and a tracking exercise. The research was prompted as police canine handlers expressed concern about the risk of heat stroke in their canines that wear ballistic vests. Raschke et al. (2013) found that there was no significant difference between the no vest and vest conditions when working at outdoor ambient temperatures ranging from 3.4°C to 20.6°C and humidity from 30% to 87%. Working while wearing a ballistic vest, made of many layers of Kevlar, did not significantly effect core temperatures in working police canines (Raschke et al., 2013).

Canine Cooling Vest Fabrications

Researchers have attempted to design vests that can alleviate the effects of radiant heat on working canines. Stalick (2008) applied to patent a method for cooling animals using Mylar, a reflective polyester film made from stretched polyethylene terephthalate. He claimed the unmoistened, two layer jacket of Mylar and light cotton mesh dropped coat temperature of dark brown or dark gray-coated canines, who were standing still in a 32.2°C environment, from 54.4-60°C to 37.8°C under normal conditions, and dropped the same starting temperatures to 26.7°C under high altitude conditions. However, no published research was found to determine its effectiveness on an active, working canine.

PMDesign and the Canadian International Demining Corps (CIDC) sought to develop a vest to promote cooling in mine detection canines. Nine garments that were made with synthetic fabrics and had reusable cooling cassettes that contained polyacrylamide crystals were developed and tested. The cassettes needed to be dunked in water or stored in a refrigerator for ideal cooling and were effective for 2 weeks before needing to be replaced. Furthermore, it took two handlers to manage the vest and cassettes when being worn on the canine and the CIDC did not find any significant differences in performance while wearing the vests (Authority and McFee, 2005). Two known attempts have been researched to reduce or alleviate the temperature effects vests have on canines; however, there was either no published research to determine the effectiveness of the vest or the methods employed showed no significant effect on core temperatures.

Statement of the Problem

Working canines must wear vests and the influence of the vest on the core temperature of the canine must be managed to avoid a degradation in the capacity of the canine to work. Materials have been created that attempt to reduce or alleviate the temperature effects of these vests, but published research was not found that has demonstrated the effectiveness of these materials or the method employed showed no significant effect on core temperatures. This study created a suit of reflective material and compared it to regular a canvas working canine vests, and a control condition, to determine if the suit, made from a metalized high density polyethylene thermoplastic, “Aluminet®”, would reduce the thermal load imposed on a canine by the environment, through reducing the amount of radiant heat absorbed by the body.

Purpose of the Study

Working canines are employed in a variety of jobs. These canines must be able to withstand the working environmental conditions while accurately and effectively performing. If a canine is not able to thermoregulate properly, it can become inefficient and unable to perform its specific task and could endanger the safety of their handler or civilians. The purpose of this study was to determine if an Aluminet® suit would reduce thermal stress imposed on a canine by the environment, through reducing the amount of radiant heat absorbed by the body; thereby, improving the canine’s ability to better tolerate the stressors of work and heat.

Chapter III

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Abstract

Thermoregulation is a critical factor for a working canine to be able to function in hot/humid environmental conditions. The purpose of this study was to determine if an Aluminet® Suit would reduce thermal stress imposed on a canine by the environment, through reducing the amount of radiant heat absorbed by the body; thereby, improving the canine's ability to better tolerate the stressors of work and heat. Fourteen working canines participated in a control and three vest/suit conditions while running on a treadmill for 20 minutes at 8 kmh-1 at a 0% grade. The results of this study showed that wearing a Canvas Vest or a Canvas/Aluminet® Vest caused significant ($P \leq 0.05$) increases in Heart Rate from Pre to Post work. There was no change in work intensity across the conditions, but increased Heart Rates Post work in the Canvas Vest and Canvas/Aluminet® Vest conditions initiated innate behavioural responses in the canines. Specifically, the canines attempted to dissipate heat by lying down, to maintain homeostasis. The results showed that wearing a vest/suit made of Canvas or Aluminet®, or a combination there of, had no significant effect on a canine's ability to thermoregulate at 27° ± 0.63°C with 60% ± 3.35 humidity.

Keywords

canine, Aluminet®, thermoregulation, vest, radiant heat, exercise

Introduction

Working canines must be able to perform in extreme conditions and not become fatigued or injured. Specialized working canines can perform jobs in detection, tracking, therapy, service, sled, police, and rescue work. If the canine becomes fatigued or injured, it become inefficient or unable to perform its specific task and could endanger the safety of the handler or civilians. Thermoregulation is crucial to the performance of a canine.

Thermoregulation is the process by which the balance of heat production and heat loss is maintained. Heat is internally generated by metabolic processes and muscular activity and externally gained from the environment. Canine thermoregulation involves conduction, convection, radiation, and evaporation to balance heat production and dissipation, so body temperature can be regulated and maintained. The thermoregulatory center in the hypothalamus controls this balance of heat dissipation and heat production to maintain body temperature and homeostasis (Flournoy et al., 2003 and Hemmelgarn and Gannon, 2013).

Normal canine temperature ranges from 37.5 to 39.2°C (Morgan, 2008), while observed exercising temperatures have been reported reaching above 41°C (Raschke, 2013, Philips et al., 1981; Wagner et al., 1977; Chapman and Baker, 1984). Temperature regulation in canines is critical for increasing working duration (Young et al., 1959, Kozlowski et al., 1985, and Kruk et al., 1985). At ambient temperatures below 32°C, convection, conduction, and radiation contribute the greatest to normothermia, but as the environmental temperature reaches body temperature, evaporation becomes the most important way for a canine to dissipate heat (Flournoy et al., 2003). Panting is a canine's primary way to regulate body temperature by increasing the evaporation of water from the respiratory tract (Crawford, 1962 and Young et al., 1959). The nasal turbinates provide a large surface area for evaporation to occur from the moist membranes (Flournoy et al., 2003). Heat and exercise have been shown to increase panting rates in canines (Chapman and Baker, 1984 and Hales and Dampney, 1975) and this heat must effectively be dissipated in order for the canine to continue working.

Working increases temperature and increasing temperatures decrease work capacity; therefore, thermoregulating while working is imperative to maintaining performance. It has been demonstrated that performance duration is dependent on canine body temperature (Kozlowski et al., 1985, Kruk et al. 1985, and Young et al., 1959). When a canine is no longer able to dissipate more heat than it produces, it will overheat and eventually cease to work. Kruk et al. (1985) determined that external cooling lowered deep body and muscle temperatures and increased exercise duration by ~45%, indicating that a lower working body temperature enhances working ability and duration.

Working canines are employed in a variety of jobs where they wear vests to be identified, protected, transported, carried, or assist humans (Cigard and Gonzalez, 2009 and Gonzalez and Cigard, 2010). Wearing a vest is a necessary piece of equipment, but adds weight and potentially heat to the canine. The effects of vests on core temperature must be managed to avoid non-productive temperatures that affect a canine's capacity to work. To address this concern, materials have been developed that attempt to reduce or alleviate the temperature effects the vests could have on the canines. However, the literature has failed to demonstrate any material that has a significant effect on core temperatures of working canines (Stalick, 2008 and Authority and McFee, 2005). Therefore, the purpose of this study was to determine if an Aluminet® Suit would reduce thermal stress imposed on a canine by the environment, through reducing the amount of radiant heat absorbed by the body; thereby, improving the canine's ability to better tolerate the stressors of work and heat.

Materials and Methods

Subjects

Fifteen adult Labrador retrievers were selected for the study. One canine was removed from the study due to its refusal to run on the treadmill, so data was collected from fourteen canines. The canines had an average age of 25 ± 10.95 months, and an average weight of 28.7 ± 3.0 kg. There were nine females and five males, and all were reproductively intact. Labrador retrievers have a double coat with a thick, dense, hard, weather-resistant top layer and a soft, downy undercoat. There were nine black coated, four yellow coated, and one chocolate coated canines in this study. Thirteen canines had medium thickness to their fur coat, while one yellow coated canine had very thick fur coat with a fuller downy undercoat. The canines were sourced from Auburn University's Canine Performance Sciences program. There was no formal conditioning program for the canines in this study; however, they did take part in a standard exercise program that consisted of nose time for detection training, regular easy-paced trotting/walking for moderate distances, as well as time for free-play; they exercised up to five days per week. Nose time means they participated in working detection problems and used their nose (olfaction) capabilities to locate positive targets. These are purposely bred and raised working canines, not pets. The nature of the project, care, and use of the canines was approved by an Institutional Animal Care and Use Committee. Prior to entering the study, each canine had a physical examination performed by a veterinarian to ensure its ability to participate in the study.

Research Environment and Environmental Temperatures

The research was conducted in an environmental room. The room was constructed to allow for the manipulation of thermal environments to recreate the conditions experienced by canines working outside at different times of the year. The room was fitted with air conditioners, heaters, heat lamps, and humidifiers.

A Wet Bulb Globe Temperature (WBGT) was used to quantify the working environment (International Standards Organization, Standard 7243, 1989). The WBGTo index is a measurement which combines the effects of humidity, air velocity, air temperature, and radiant heat into one single index. Each sample was recorded at a height of 75 cm relative to the ground and next to the treadmill where the canine was running, which gave an assessment of the thermal load on the canine.

The WBGTo temperature and humidity of the chamber was held constant at 27° ± 0.63°C / 60% ± 3.35 respectively, to create an environment that was similar to the average climate report for the Auburn, AL area, from the National Weather Service in Birmingham, AL from July of 2014. There were five 250W, 120V Infrared Clear Heat Lamps hanging from the ceiling of the room to simulate outdoor radiant heat (see figure 1). The WBGT was recorded 5 minutes into the 20 minute run of each canine, but was monitored continuously during each trial to maintain the correct temperature.

A fan was used to circulate and mix the air to prevent micro climates from forming around the canine or the equipment and to simulate running outside. Similar to Taylor et al.'s study (1971), a fan was placed perpendicular to the canine on the running surface and the wind speed was maintained at 4.8 kmh-1.

Figure 1: Canine on treadmill with IR lights hanging from ceiling.

Work Intensity/Conditions

Physical fitness plays a large role in an animal's ability to thermoregulate. The canines in this study did not go through a standardized condition program, but are from a pool of specifically bred and trained group of detection canines that received detection canine nose time and exercised up to five days a week. Nose time means the canines participated in working detection problems and used their nose (olfaction) capabilities to locate positive targets. The canines in this study lived in indoor/outdoor kennel runs and were acclimatized to the thermal load selected for this study. The canine was tasked to run on a JogADog® treadmill for 20 minutes at 8 kmh-1 at a 0% grade (JogACanine®, LLC. 5051 Piehl Rd., Ottawa Lake, MI 49267, USA.). The canines were acclimated to treadmill running 3-5 days prior to data collection to ensure each canine was comfortable running on the treadmill and to ensure there would not be any false anxiety/anticipation that effected the physiological parameters during data collection. The work intensity component of this study was modelled after Sneddon et al. (1989), Wyatt and Mitchell (1974), Gillette and Angle (2011), and Taylor et al.'s (1971) studies. The methodology utilized in those studies had canines exercise at workloads that ranged between 6.4-12.8 kmh-1 at 0-10% inclines for a duration between 20 minutes to 1 hour. The intensity of the work load was expected to show a significant increase in the canine's temperature.

Canine Exercise Conditions

Each canine participated in data collection during the morning hours between 8am-12 pm, for four consecutive days, in random condition order. One condition/treadmill running activity occurred per day.

The four conditions were:

1. Canine Control with no added suit/vest (Dog Condition)
2. Canine with Canvas vest (typical service/working canine canvas vest) (Canvas Vest Condition)
3. Canine with Canvas vest with the Aluminet® material placed over the Canvas vest (Canvas/Aluminet® Vest Condition)
4. Canine with Aluminet® Suit (Aluminet® Suit Condition)

The Aluminet® Suit covered 723.9 cm^2 of the canine's body, while the Canvas Vest and the Canvas/Aluminet® Vest covered 346.7 cm^2 of the canine's body. The Canvas vest weighed 270g; the Canvas/Aluminet® Vest weighed 320g (270g Canvas, 50g Aluminet® material); and the Aluminet® Suit weighed 70g. Prior to conducting the study, thermal penetration was tested on the canvas material, and in a 20 minute period, the temperature of the underside of the canvas was 1°C higher than the temperature on the canvas outside.

Aluminet® Suit

Aluminet® (Patent US 8978342 B2, 2015) is a mesh material made from a metalized high density polyethylene (HDPE) thermoplastic. Variations in the mesh construction are defined by the percentage of HDPE material to air gap surface area (e.g., 50% has 50 percent exposed HPDE material with 50 percent open air gaps). Aluminet® is available in five varieties, categorized by the percent shade provided. Standard widths range from about 6.5 to 28 feet and roll lengths are available up to about 1600 feet. Typically used in greenhouse settings, it has shown to reduce greenhouse temperatures by

9-14%. The material is durable, does not unravel, it can be cut and sewn at any angle with no fraying or damage to the cloth under normal use, and maintains a five-year warranty against ultra-violet exposure in greenhouse applications (Pascoe et al., 2015). The Aluminet® material was sewn into a suit for the canine. The suit covered the entire back of the canine from just below the collar down to the tail. Two cotton straps that went under the belly, a chest strap, and a strap to the collar were used for holding the material in place. The Aluminet® 50% weave was used to construct the suit. A 50% weave means that the material will alleviate 50% of the radiant heat load.

Procedures for Collection of Physiological Data and Infrared Thermal Imaging

Two forms of core temperature, Rectal and Deep Body, were collected during this study. Both were necessary because of the time of collection. The Deep Body Temperature method was able to be collected during exercise, while the Rectal Temperature method could only be collected before and after exercise. Rectal Temperature was recorded by a Welch Allyn Sure Temp Plus Rectal Thermometer that was covered in a plastic sheath and inserted 7 cm into the rectum of a canine. It was placed on the external wall of the rectum to avoid fecal matter, which could alter temperature reading. The Welch Allyn system has a specified accuracy of ± 0.1°C and was recalibrated prior to its use during this project. Rectal Temperatures were taken Pre-Exercise, Post-Exercise, Post 10 minutes, and Post 20 minutes. Deep Body Temperature was recorded by a Yellow Springs temperature monitor system with an insulated/flexible rectal probe that was attached to the canine’s collar and then run down the back of the canine to attach to the tail with white athletic tape then inserted 10 cm into the rectum of the canine. This flexible probe was able to travel 3 cm further than the Welch

Allyn system and was able to collect temperature during exercise. The Yellow Springs system was used to take the canine’s temperature at Pre-Exercise, Post-Exercise, Post 10 minutes, and Post 20 minutes, and was sampled every 5 minutes during the 20 minute treadmill running session. Rectal and Deep Body values were averaged together to get one Core Temperature Value.

A portable multi-parameter Veterinary Monitor (VET400A) was used to record electrocardiogram (EKG) data to obtain Heart Rate in beats per minute. Respiratory Rate was evaluated via auscultation and was reported as the number of breaths inspired/expired per minute. Heart Rate and Respiratory Rate were taken Pre-Exercise, Post-Exercise, Post 10 minutes, and Post 20 minutes.

A FLIR SC660 Infrared Thermal Imaging (IR) Camera was used to capture thermal images of the face/nose of the canine to look for temperatures and patterns associated with the environmental conditions. IR face/nose images were taken Pre-Exercise, Post-Exercise, Post 10 minutes, and Post 20 minutes.

Statistical Analysis

SPSS version 22.0 was used for all statistical analyses. For the variables of Heart Rate, Rectal Temperature, Deep Body Temperature, Respiratory Rate, and Maximum IR Nose Temperatures, a repeated measures ANOVA was used with factors of Time (Pre versus Post Treadmill Run) and Condition (Dog, no vest), Canvas Vest, Canvas/Aluminet® Vest, and Aluminet® suit). The same variables were analyzed during the Recovery phase with factors of Time (Post versus Post 10 versus Post 20) and Condition (Dog, no vest), Canvas Vest, Canvas/Aluminet® Vest, and Aluminet® suit).

Statistical assumptions of the ANOVA were met for all variables and the significance level was set at alpha ≤ 0.05.

In order to follow-up a significant Time (Pre-, Post-Test) by Condition interaction in Heart Rate, a series of dependent t-tests were used to compare Pre- to Post-Test in each condition separately. Similarly, in order to follow up a significant Time (Post, Post10, Post20) by Condition interaction for Heart Rate, we conducted follow-up repeated measures ANOVA with single factor of Condition for each time point, separately.

Results

Physiological Parameters

- The canines in the Canvas Vest and Canvas/Aluminet® Vest conditions had significant ($P \leq 0.05$) increases in Heart Rate from Pre to Post work.
- All conditions had a significant ($P \leq 0.05$) decrease in Heart Rate from Post to Post 10 work.
    - The canines wearing the Canvas Vest and Canvas/Aluminet® Vest consistently laid down on the ground after the treadmill run during Post work recovery.
    - The canines in the Dog and Aluminet® conditions consistently sat on their bottoms and did not want to lay on the floor during Post work recovery.
    - Heart Rate in the Canvas Vest and Canvas/Aluminet® Vest conditions, Post to Post 10, showed the largest significant decrease of 29 and 20 beats per minute, respectively, when the canine was lying down on the floor.
    - Heart Rate during the Dog and Aluminet® Suit conditions demonstrated smaller significant decreases of 16 and 15 beats per minute, respectively, when the canines were sitting on their bottoms during recovery.
- Pre Heart Rate values in the Dog condition when compared to the other three conditions had a P value of 0.052.
- The study resulted in no significant difference ($P > 0.05$) between conditions for Heart Rate.

Figure 2 below shows the average Heart Rate and standard deviations across conditions.

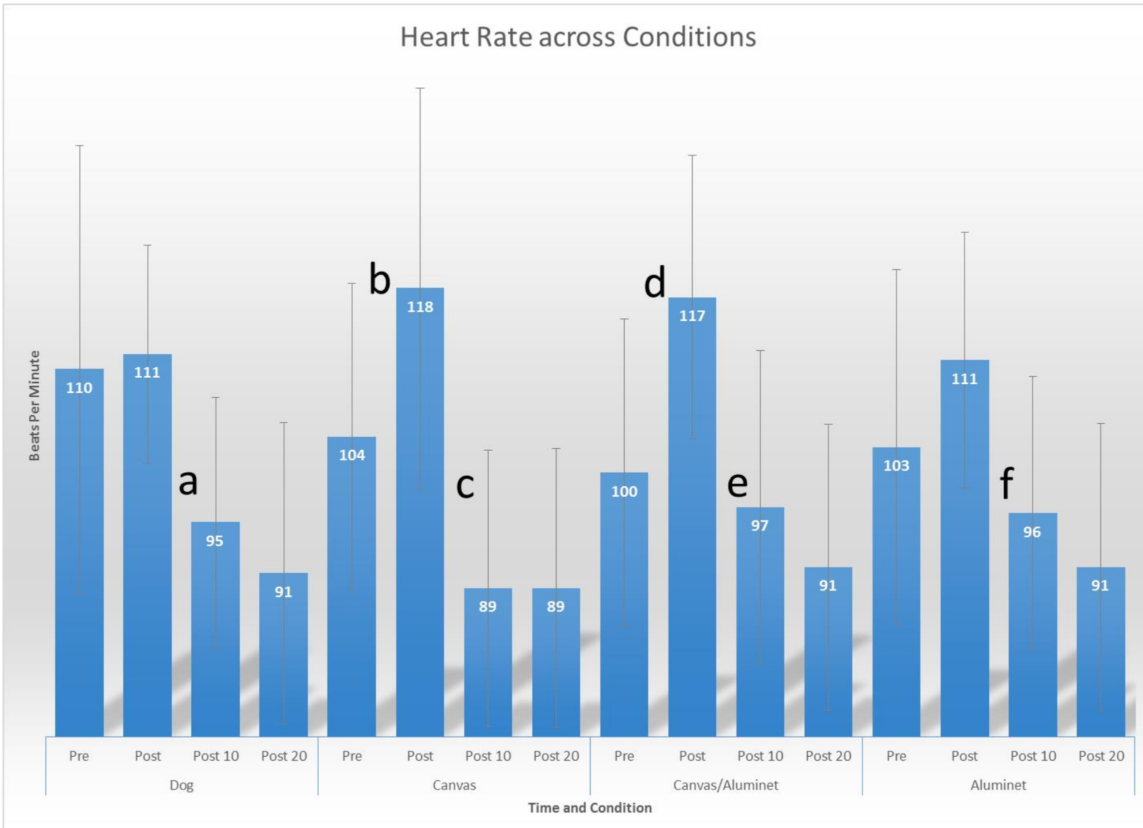


Figure 2: Heart Rate across Conditions.

- Statistical significance ($P \leq 0.05$), is noted with an (a, b, c, d, e, f) and only pertains within that condition and to that particular time point.
- The Canvas Vest and Canvas/Aluminet® Vest conditions had statistically significant ($P \leq 0.05$) increases, Pre to Post work (noted with the b and d).
- All conditions had a significant ($P \leq 0.05$) decrease in Heart Rate during Post to Post 10 work (noted with a, c, e, and f).
- Pre Heart Rate in the Dog Condition compared to the other three conditions, had a P value of 0.052.

There was an increase in Maximum IR Nose Temperatures from Pre to Post work in all four conditions. The Maximum IR Nose Temperatures in the Canvas Vest and Canvas/Aluminet® Vest conditions decreased Post to Post 20 work. The Maximum IR Nose Temperatures in the Dog and Aluminet® conditions maintained a relatively even temperature Post to Post 20 work. However, the study resulted in no significant (P>0.05) difference between conditions for Maximum IR Nose Temperature. Figure 3 below shows average Maximum IR Nose Temperatures and standard deviations across conditions.

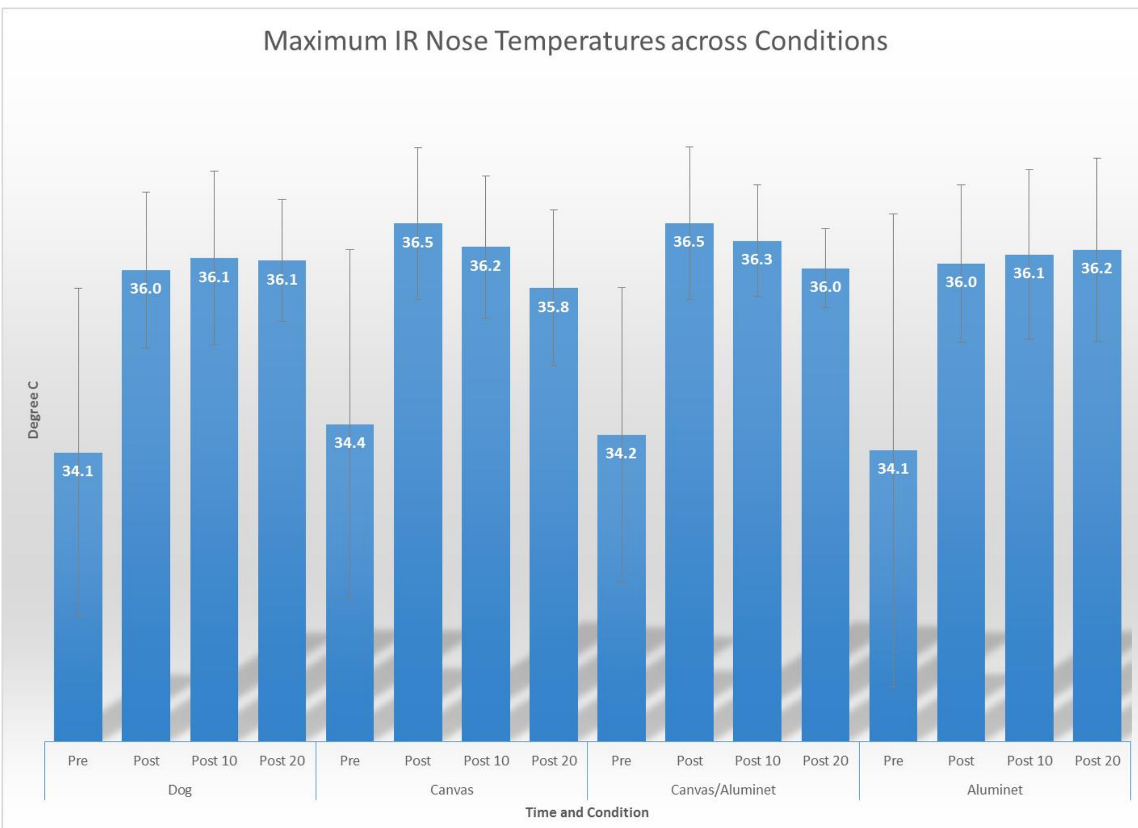


Figure 3: Maximum IR Nose Temperatures across Conditions

The average Pre value for Core Temperatures of all canines was 38.7°C ± 0.35. There was an increase in Core Temperature from Pre to Post work in all four conditions and a decrease Post to Post 20 work. However, the study resulted in no significant difference (P>0.05) between conditions for Core Temperature. Figure 4 below shows the average values and standard deviations for Core Temperature across conditions.

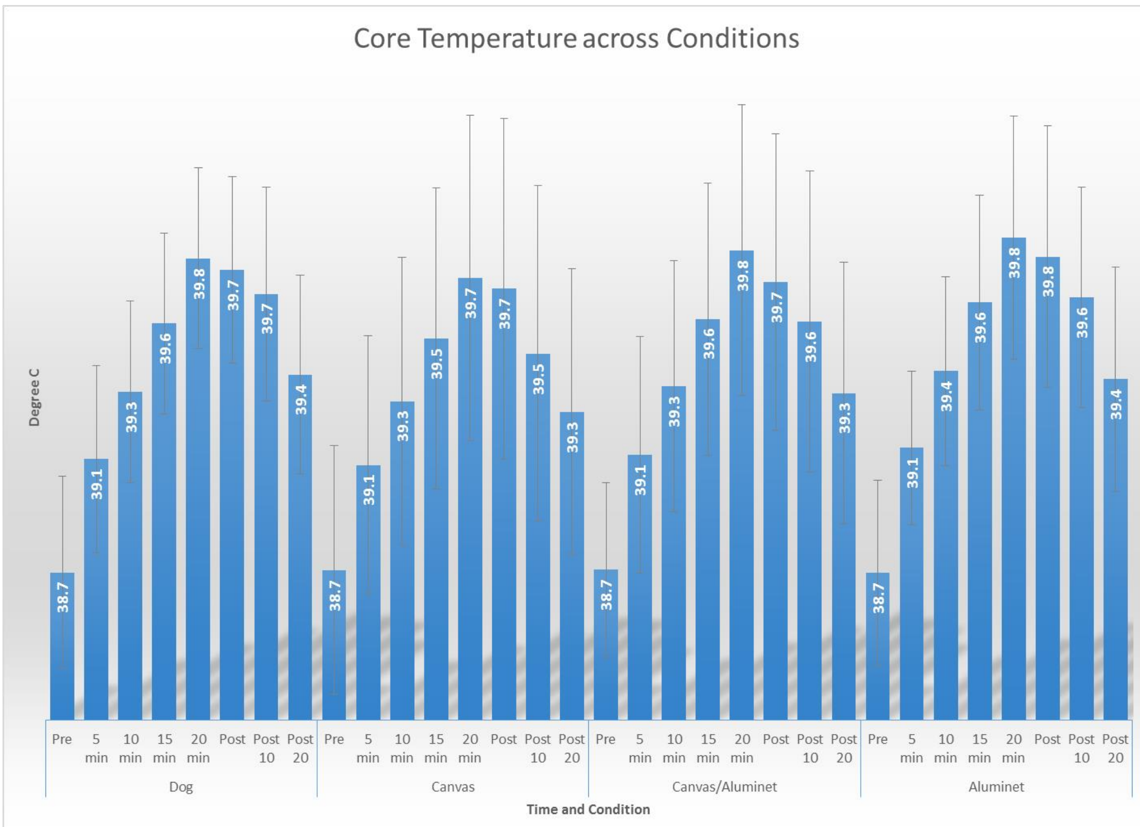


Figure 4: Core Temperature across Conditions

There was an increase in Respiration from Pre to Post work and a decrease Post to Post 20 work across conditions. However, the study resulted in no significant difference (P>0.05) between conditions for Respiratory Rate. Figure 5 below shows the average values and standard deviations for Respiratory Rates across conditions.

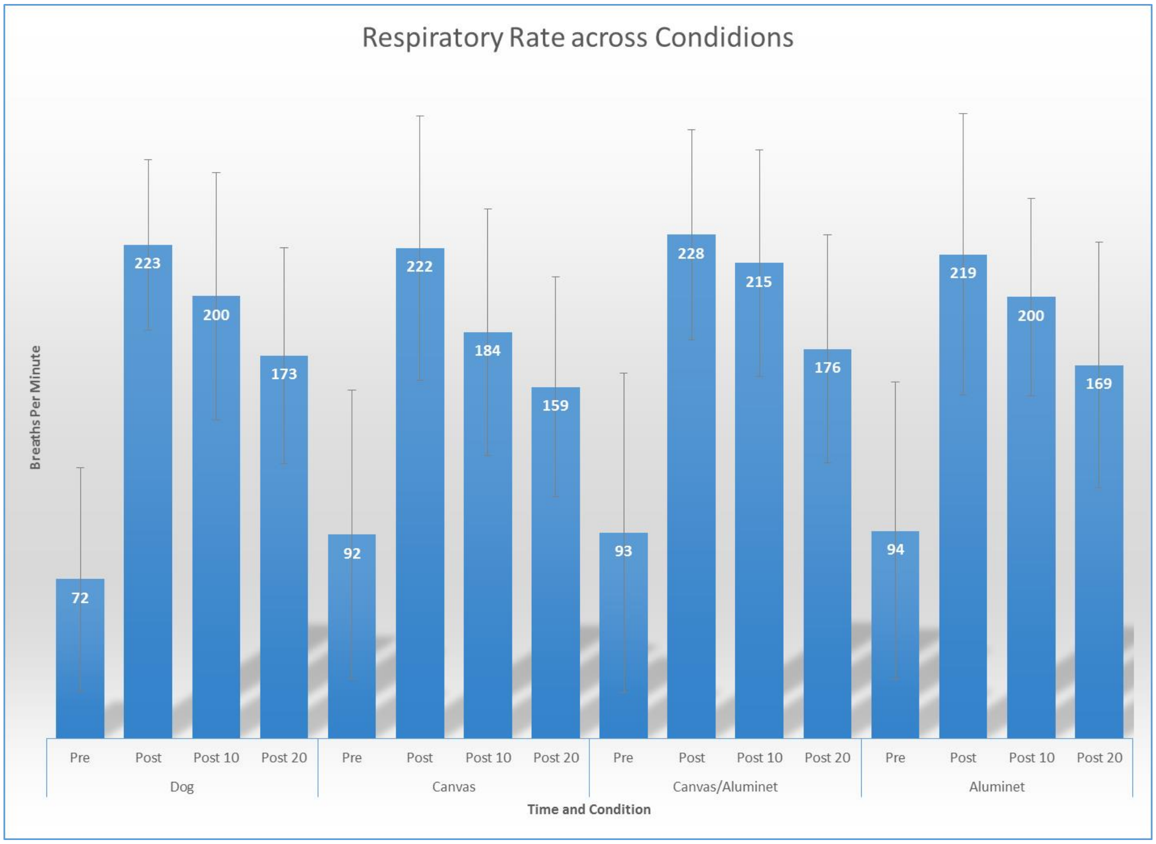
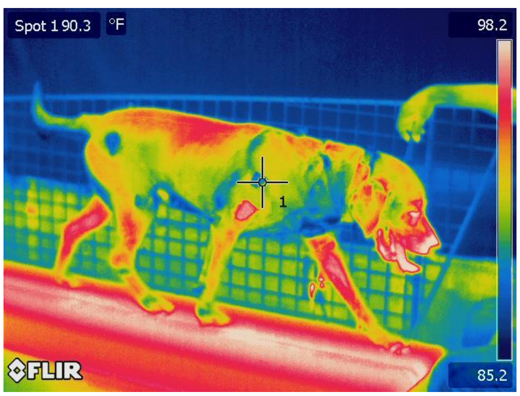
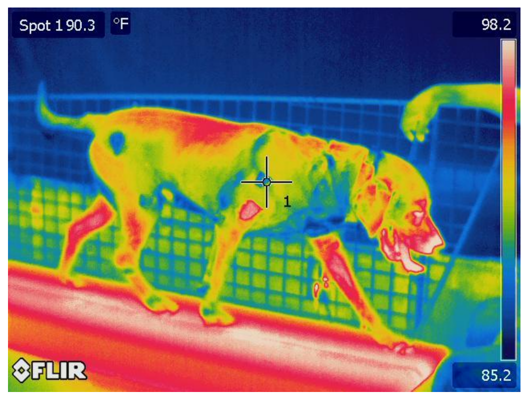


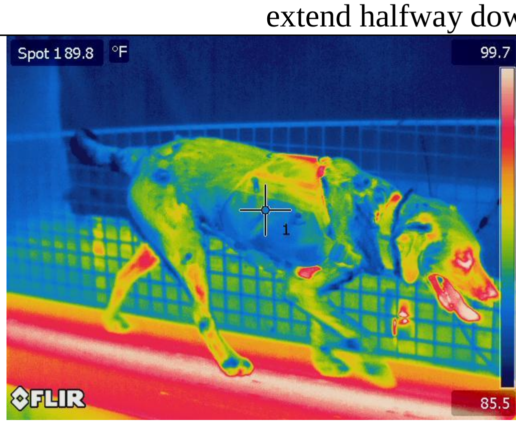
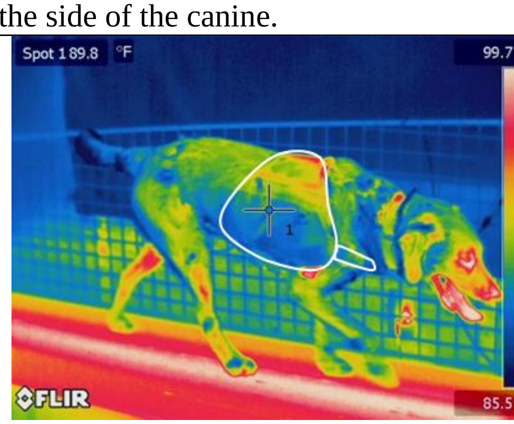
Figure 5: Respiratory Rates across Conditions

Infrared Imaging

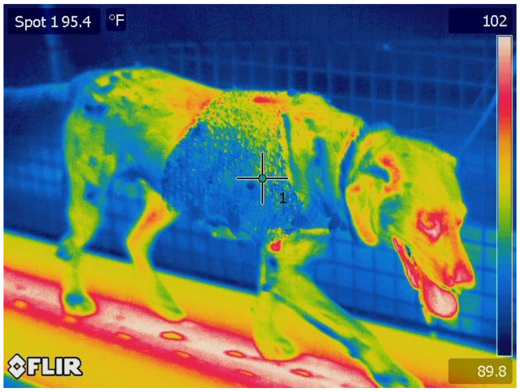
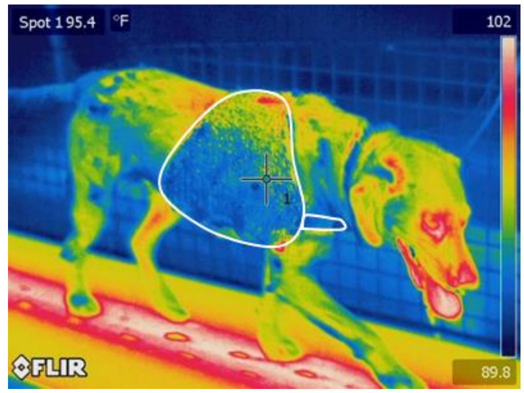
Infrared images allow body temperatures and patterns to be displayed. The regions of interest in the present study include the canine's nasal cavities, tongue, dorsal spine (back) and shoulders. The Aluminet® Suit covered 723.9 cm² of the canine's body. The Canvas Vest and the Canvas/Aluminet® Vest covered 346.7 cm² of the canine's body. Table 1 below shows the comparisons between each condition and coverage area of vest/suit. The vest/suit and straps, that hold the material in place, are outlined in white.

<table>
<tr><td colspan="2">Dog (No Vest) Condition

No Coverage
The canine in the Dog condition is hotter than the other three conditions.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Canvas Condition

Vest covered 346.7 cm² of canine
The temperature pattern for the Canvas Vest is the hottest vest of the three vest/suit conditions. The Canvas Vest is hottest along the apex and the warmer temperatures extend halfway down the side of the canine.</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

<table>
<tr><td colspan="2">Canvas/Aluminet® Condition

Vest Covered 346.7 cm² of canine
The Canvas/Aluminet® Vest is hottest at the apex and the warmer temperature extend a quarter of the way down the side of the dog.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Aluminet® Condition

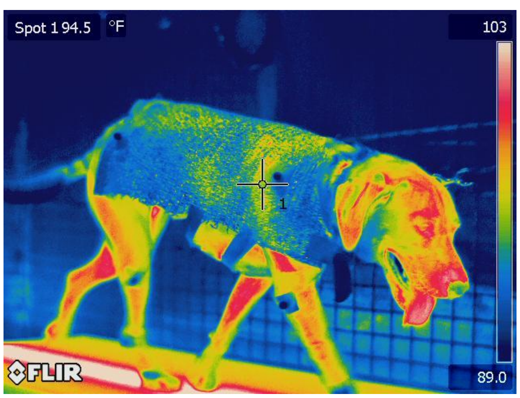
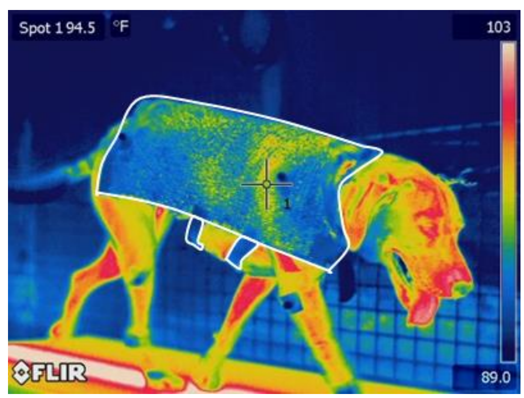
Suit covered 723.9 cm² of canine
The Aluminet® Suit covers the entire back of the canine and the material is cooler than the other areas on the canine.</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 1: IR Images of Canines Running during all Conditions. The vest/suit and straps, that hold the material in place, are outlined in white to display the temperature patterns and areas of coverage.

IR Nose Temperature increased Pre to Post work. Table 2 below shows the average increase and standard deviation during each condition.

IR Nose Temperatures in °C								
Condition	Dog		Canvas		Canvas/Aluminet		Aluminet	
Time	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Avg.	34.1	36.0	34.4	36.5	34.2	36.5	34.1	36.0
StDev.	1.7	0.8	1.8	0.8	1.6	0.8	2.5	0.8

Table 2: IR Nose Temperatures Pre to Post across Conditions

Table 3 below shows how the work effects nasal temperatures Pre to Post work. Post work the canine has an increase in temperature in the nasal and oral cavities. It is panting heavily with its mouth open.

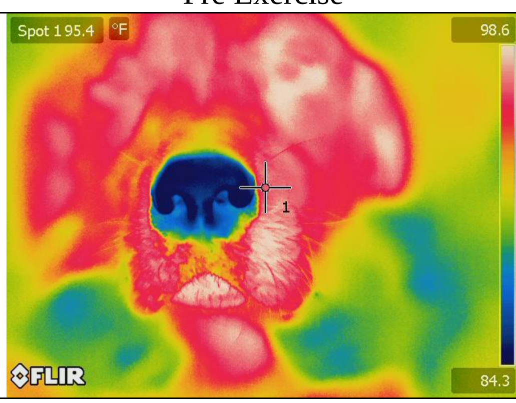
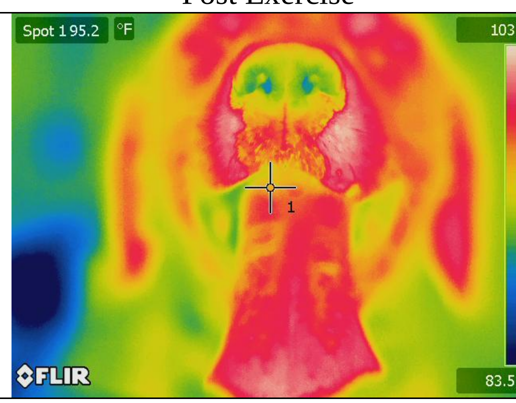
Pre Exercise	Post Exercise
	

Table 3: IR Image of a Canine Pre and Post Treadmill Run

Post work, canines panted heavily with their mouths open. Table 4 below shows Pre to Post work average Respiratory Rates and standard deviations during each condition.

Resiratory Rates in Breaths per Minute across Conditions								
Condition	Dog		Canvas		Canvas/Aluminet		Aluminet	
Time	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Avg.	72	223	92	222	93	228	94	219
StDev.	51	39	65	60	72	48	67	64

Table 4: Respiratory Rates Pre to Post across conditions

Table 5 below shows Pre to Post 20 work IR nose temperatures for all conditions. Post work in all conditions, the canine has an increase in temperature in the nasal and oral cavities and its panting heavily with its mouth open.

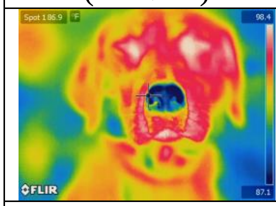
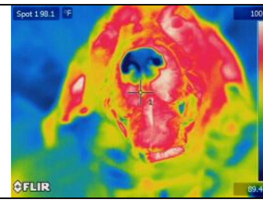
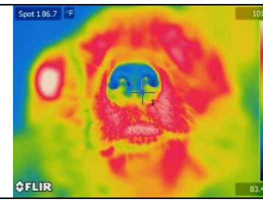
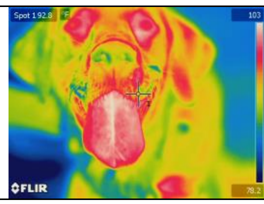
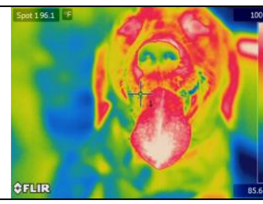
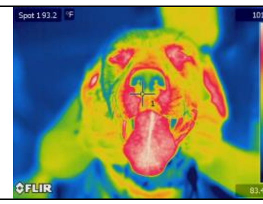
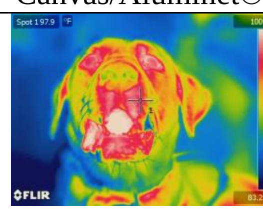
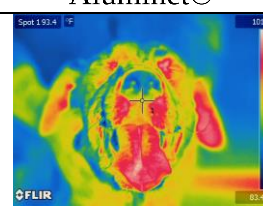
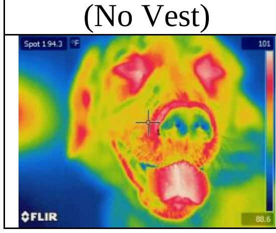
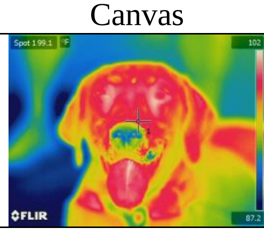
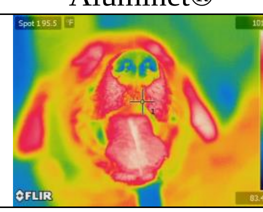
Pre Dog (No Vest)	Pre Canvas	Pre Canvas/Aluminet®	Pre Aluminet®
			
Post Dog (No Vest)	Post Canvas	Post Canvas/Aluminet®	Post Aluminet®
			
Post 10 Dog (No Vest)	Post 10 Canvas	Post 10 Canvas/Aluminet®	Post 10 Aluminet®
			
Post 20 Dog (No Vest)	Post 20 Canvas	Post 20 Canvas/Aluminet®	Post 10 Aluminet®
			

Table 5: IR Nose Temperatures across Conditions

Discussion

The canines in the Canvas Vest and Canvas/Aluminet® Vest conditions had significant ($P \leq 0.05$) increases in Heart Rate from Pre to Post work. The work intensity remained the same throughout all of the conditions, yet the canines wearing the Canvas Vest and Canvas/Aluminet® Vest consistently lay down on the floor after the treadmill run during the Post work recovery period. Observations of the significant increase in Heart rate Pre to Post work and the canines' behavioural changes (i.e. lying, instead of sitting, on the floor) in the Canvas Vest and Canvas/Aluminet® Vest conditions suggest that the dogs may have perceived these vest trials differently from the control and Aluminet® trials.

All conditions had a significant ($P \leq 0.05$) decrease in Heart Rate from Post to Post 10 work, mainly because activity had stopped, but the amount of decrease was largely affected by the canines' behavior during that period. Heart Rate in the Canvas Vest and Canvas/Aluminet® Vest conditions, when the canine was consistently lying on the floor Post to Post 10 work, showed the largest significant decrease of 29 and 20 beats per minute, respectively. The best way for a canine to conduct heat to another surface occurs through the underbelly (Kruk et al., 1985 and Flournoy et al., 2003). In the Dog and Aluminet® Suit conditions, when the canine consistently sat Post to Post 10 work, significantly, lower decreases of 16 and 15 beats per minute, respectively, were observed. In this study behavioural differences in the canines were observed only when wearing a Canvas Vest or Canvas/Aluminet® Vest.

The Aluminet® material was chosen for this study because it has practical applications that have been demonstrated on buildings and humans. The Aluminet®

material decreased the internal temperature of a house or vari-kennel dog crate an average of 5.6°C. In humans wearing an outfit fashioned from the Aluminet® material, the temperature underneath the Aluminet® material averaged 5.6°C lower than the part of the material that was exposed to radiant heat (Pascoe unpublished data, 2015). A material that is capable of reducing temperatures on buildings and people, by blocking 50% of the radiant heat load, should reduce the same heat load and have similar effects on a canine. Reducing the heat load should allow the canine to better tolerate the stressors of work and heat; thereby, allowing it to work longer. The work intensity in this study was modelled after Sneddon et al. (1989), Wyatt and Mitchell (1974), Gillette and Angle (2011), and Taylor et al.'s (1971) studies and was expected to show a significant increase in the canine's temperature. Yet, no significant thermoregulatory changes between conditions were observed. The results of this study show that, during a 20 minute bout of exercise at 27° ± 0.63°C with 60% ± 3.35 humidity, wearing a vest/suit made of Canvas or Aluminet®, or a combination there of, has no significant effect on a canine's ability to thermoregulate. The results of this study line up with the results of Raschke et al. (2013) and Authority and McFee (2005) studies' in the fact that their vest conditions had no significant effect on core temperatures or performance. The canines in this study were able to respond accordingly to the level of work and environmental stressors, so significant thermoregulatory differences ($P \leq 0.05$) between the control condition and the three vest/suit conditions emerged.

Limitations

Excitement and Anticipation

It has been shown that excitement and anticipation have significant effects on the vital signs of canines bred and trained to perform selected activities (Gillette et al., 2011). The canines in this study were selected and bred for their independence and motivation to work, but remain highly responsive to their handler. During the Post work recovery periods, the researchers had to sit quietly appearing like an object in the room because these purposely bred canines would respond to slightest body movement, noise, and even eye contact. They were selectively bred and trained to do detection work and are easily excited at any indication that they will return to work. The canines were not exhausted from the work intensity of this study and because they were excited to return to work, their vital signs could have easily been affected during recovery.

Another limiting factor was the canines in this study regularly did detection work when wearing a Canvas Vest and non-vest time associated with free play. The Aluminet® Suit weighed 70g, Canvas Vest weighed 270g, and the Canvas/Aluminet® Vest together weighed 320g. The absence of that small amount of weight on the canine's back and its knowledge that no vest meant free play could have caused the canine to remained excited, which could have affected the Pre Heart Rate values in the control condition.

Pre Heart Rate in the Dog condition was not significant (P=0.052), but in three conditions in which the dogs wore a vest/suit, heart rates were considerably lower than the control. The canines in this study were trained detection canines and they would stand and hold their position while a working vest was being secured. The lower Heart Rates across conditions could be attributed to the interaction between the handler and canine. The canine knew to stand still and wait while a vest is being secured, or simply wearing a vest could have calmed the canine and reduced its stress. Vests can have therapeutic effects by reducing a canine's anxiety (Cottam et al., 2013 and Blizzard, 2014).

Work Intensity

The canines in this study averaged Core Temperatures of 39.7°C ± 0.5 Post work. Gillette and Angle (2011) reported that unconditioned canines averaged 40.4 ± 0.6°C post-exercise after a 20 minute, 3.5 km run, while working canines are reported typically reaching temperatures above 41°C (Raschke, 2013, Philips et al., 1981; Wagner et al., 1977; Chapman and Baker, 1984). The selected study work intensity and thermal load, of 27° ± 0.63°C at 60% ± 3.35 humidity, may have not been intense enough to show significant increases in temperature for these purposely bred and trained working canines that were included in this study.

Conclusions

Thermoregulation is a critical factor for a canine to remain working in hot/humid climatic conditions. The canines in Canvas Vest and Canvas/Aluminet® Vest conditions may have perceived the work as harder as sensed from their significant Heart Rate increases Pre to Post work. Only in those trials did the canines' choose to lie down rather than sit on the floor, during post work.

Under these test conditions, a 20 minute bout of exercise at 27° ± 0.63°C with 60% ± 3.35 humidity, wearing a vest/suit made of Canvas or Aluminet®, or a combination there of, did not demonstrate a significant effect on a canine's ability to thermoregulate. Yet, the canines behaved differently only during the trials when a canvas vest was worn. When testing the heat transfers from the radiant heat source, the inside of the Canvas Vest increased by 1°C in only 20 minutes. The Aluminet HPDE 50 has metallic material that makes up 50% of the surface area and blocks 50% of the radiant heat load. The Aluminet® material reduces the thermal heat load on buildings and in humans, and has shown decreases in temperature of 5.6°C during temperature extremes. More research is needed with working canines wearing an Aluminet® Suit while exercising in hotter climatic conditions, and under conditions that require a canine to work for longer durations and higher intensities. Under these harsher conditions, the Aluminet Suit's ability to reduce the thermal heat load, may significantly improve the canine's ability to better tolerate the stressors of work and heat.

Future Research

Working canines must be able to perform in extreme conditions and not become fatigued or injured. A working canine in theatre, could work in conditions ≥ 45°C for extended periods of times, in excess of eight hours a day (Toffoli and Rolfe, 2006) and employed service canines are expected to work around the clock, remaining with their handler wherever they go, inside or outside. The canine needs protection to reduce the radiant heat load felt on the body because working canines must wear vests. More research needs to be done with a canine working at higher temperatures and for longer durations with the Aluminet® material to determine how hot and how long the canine would be able to work. The Aluminet® suit needs further examination because it should work, like it does on buildings and humans, to reduce the amount of radiant heat absorbed by the body; thereby, improving the canine's ability to better tolerate the stressors of work and heat. More research also needs to be conducted with a canine working for a longer period of time in a hotter temperature environment to determine how long it takes for radiant heat to penetrate a Canvas or Kevlar vest and affect a canine's ability to thermoregulate.

Acknowledgements

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