Effects of a whole-body spandex garment on rectal temperature and oxygen consumption in healthy dogs

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Objective—To determine whether a full-body spandex garment would alter rectal temperatures of healthy dogs at rest in cool and warm environments.

Design—Prospective study.

Animals—10 healthy dogs.

Procedures—Each dog was evaluated at a low (20° to 25°C [68° to 77°F]) or high (30° to 35°C [86° to 95°F]) ambient temperature while wearing or not wearing a commercially available whole-body spandex garment designed for dogs. Oxygen consumption was measured by placing dogs in a flow-through indirect calorimeter for 90 to 120 minutes. Rectal temperature was measured before dogs were placed in the calorimeter and after they were removed.

Results—Rectal temperature increased significantly more at the higher ambient temperature than at the lower temperature and when dogs were not wearing the garment than when they were wearing it. The specific rate of oxygen consumption was significantly higher at the lower ambient temperature than at the higher temperature.

Conclusions and Clinical Relevance—Results suggest that wearing a snug spandex body garment does not increase the possibility that dogs will overheat while in moderate ambient temperatures. Instead, wearing such a garment may enable dogs to better maintain body temperature during moderate heat loading. These results suggest that such garments might be used for purposes such as wound or suture protection without causing dogs to overheat. (*J Am Vet Med Assoc* 2004;224:71–74)

Body garments are placed on dogs for a variety of reasons, including to reduce shedding of fur into the living environment and protect the skin and coat from trauma. In addition, body garments may be used to bandage traumatic wounds in areas of the body that are otherwise difficult to cover and to prevent self-mutilation.

Very little is known regarding the effects currently available garments might have on the normal physiologic responses of dogs. A cause of potential concern for dog owners and veterinarians is whether wearing a full-body garment might impair a dog's ability to regulate its body temperature. Full-body garments and splints made of spandex are being used increasingly often in human medicine, particularly as an adjunct to traditional physical therapy in patients with cerebral palsy and stroke.[1,2] Early reports regarding the use of these garments in humans have indicated somewhat encouraging results, with improved function in these patients and positive comfort ratings. However, the thermoregulatory mechanisms of humans and dogs are dramatically different, and the potential for body garments to increase the risk of hyperthermia should be fully examined prior to their widespread use in dogs.

The purpose of the study reported here was to determine whether a full-body spandex garment would alter rectal temperatures or oxygen consumption of healthy dogs at rest in cool and warm environments. We hypothesized that the garment would add insulation and impair the dogs' abilities to exchange heat with the environment, potentially leading to hyperthermia.

Materials and Methods

Dogs—Twelve healthy dogs were used in the study. None of the dogs had any history of clinically relevant medical problems, and for all dogs, results of a physical examination, CBC, and serum biochemical profile performed immediately before the study were normal. Mean ± SD body weight was 17.5 ± 7.7 kg (38.5 ± 16.9 lb; range, 8.2 to 28.7 kg [18 to 63.1 lb]). Long- and short-haired dogs were used, including 2 Golden Retrievers, 2 Labrador Retrievers, a Norwegian Elkhound, a Beagle, a mixed-breed terrier-type dog, an American Pit Bull Terrier, a Border Collie mix, a Dachshund mix, a West Highland White Terrier, and a Corgi mix. All dogs were familiarized with the experimental room and measurement chamber and had worn the garment used in the study at their homes prior to the study. Dogs were weighed on a digital scale prior to each experimental trial.

Experimental protocol—A split-plot design with 2 variables, temperature and garment, was used. The study protocol was approved by the University of California, Davis, Institutional Animal Care and Use Committee.

Each dog was evaluated at a low (20° to 25°C [68° to 77°F]) or high (30° to 35°C [86° to 95°F]) ambient temperature while wearing or not wearing a commercially available whole-body spandex garment designed for dogs.[a] Garments were designed to cover the trunk and limbs and were fitted to each dog; they had a nylon zipper closure on the ventral midline and hook-and-loop closures on the neck and limb openings (**Fig 1**).

For each experimental trial, the room in which the trial was to be conducted was brought to the appropriate ambient

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Presented at the 30th Annual Conference of the Veterinary Orthopedic Society, Steamboat Springs, Colorado, March 2003.

Supported by the K-9 Top Coat Company.

The authors thank Drs. Lyn Smith and Jarred Lyons for technical assistance and John Doval for assistance with the illustration.

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Figure 1—Photograph of a dog wearing a spandex body garment.

temperature with a thermostatically controlled air-conditioning unit or steam coil heater. The dog was weighed and, if indicated by the protocol, dressed in the garment. Its rectal temperature was then measured, and the dog was placed in a flow-through indirect calorimeter in the room. The dog remained in the calorimeter for 90 to 120 minutes until its **rate of oxygen consumption ($\dot{V}O_2$)** reached a steady state. It was then removed from the calorimeter, and its rectal temperature was again recorded.

Experimental trials were performed at various times during the day or evening; however, for any given dog, all 4 experimental trials were performed during the same time of day to minimize the effects of diurnal rhythms. Whether dogs were first tested wearing or not wearing the garment was randomly assigned. However, because of logistic constraints, it was necessary to conduct all low-temperature experimental trials prior to the high-temperature experimental trials.

Measurement of rectal temperature—Rectal temperatures were measured with a type-T thermocouple.[b] The tip of the 24-gauge thermocouple wire was glued in a 6-mm-diameter plastic sleeve. For measurement of rectal temperature, the sleeve was coated with petroleum jelly and inserted approximately 6 cm into the rectum (distance varied slightly with dog size). The thermometer was allowed to equilibrate before rectal temperature was recorded.

Measurement of oxygen consumption—A flow-through indirect calorimeter was used to measure $\dot{V}O_2$ (**Fig 2**). The calorimeter was constructed from an intensive care oxygen delivery cage[c] that was 82 cm high, 100 cm wide, and 70 cm deep. The chamber volume was reduced by 50% for dogs that weighed < 20 kg (44 lb) by affixing a plastic acrylic barrier across the center of the chamber. The chamber was sufficiently large so that all dogs could stand up and turn around while in it. A 15-cm-diameter oscillating fan was mounted inside the calorimeter to circulate air in the chamber and promote gas mixing. Ambient temperature and relative humidity in the chamber were continuously measured with a digital thermohygrometer.[d] A closed-circuit video camera was used to monitor the dogs while they were in the calorimeter. An observer in another room could watch the dog and the data being collected without exciting the dog and could enter the experimental room to check or adjust equipment without being seen by the dog in the chamber.

Ambient air was drawn through peripheral vents into and through the calorimeter chamber with a 5-horsepower commercial shop vacuum cleaner controlled by a rheostat. The shop vacuum cleaner was connected to a 1.9-cm-diameter exhaust port in the calorimeter by 1.9-cm-diameter flexible tubing and a PVC pipe. Bias flow rate through the system was measured with a mass-flow meter[e] in series with the PVC pipe and with a pneumotachometer.[f] Differential pressure transducers[g] measured static pressure in the bias flow line and the pressure drop across the pneumotachometer. Flow was controlled by adjusting the rheostat on the shop vacuum cleaner so that flow was constant. Gas passing through the bias flow line was exhausted outside of the experimental room so as to not alter the ambient concentration of O_2 surrounding the dog.

Distal to the mass flow meter, a sample of the gas pulled from the chamber (room air plus expired gases from the dog) was drawn from the bias flow line with a diaphragm pump[h] and analyzed with an O_2 analyzer.[i] Before the gas sample reached the analyzer, it was passed through columns of $CaSO_4$[j] and NaOH[k] to remove water and CO_2 from it. Signals from all transducers were passed through an analog-digital converter[l] and recorded on a computer.[m]

Prior to each experimental trial, while room temperature was equilibrating, baseline ambient O_2 concentration in the calorimeter chamber was measured. Bias flow was set at a value estimated from preliminary trials to result in a ≤ 1% decrease in O_2 concentration when the dog reached steady-state $\dot{V}O_2$. Throughout the measurement procedure, a second channel on the O_2 analyzer was used to monitor ambient air to ensure that ambient O_2 concentration did not change during the trial. After the dog was removed from the calorimeter chamber, the bias flow line was switched to ambient air and ambient O_2 concentration was again measured. A flow of N_2 was then introduced into the bias flow line with a rotameter to decrease O_2 concentration in the bias flow line by the same amount as when the dog was in the calorimeter. Flow rate through the rotameter was calibrated by bleeding N_2 into a volumeter and timing the rate of volume change. After correction to standard temperature, pressure, and dry units, this flow of N_2 was then used to calculate the specific rate of O_2 consumption ($\dot{V}O_2$/kg) for the dog; standard equations were used.[3]

Statistical analyses—Data are expressed throughout as mean ± SD. Changes in rectal temperature and $\dot{V}O_2$/kg were

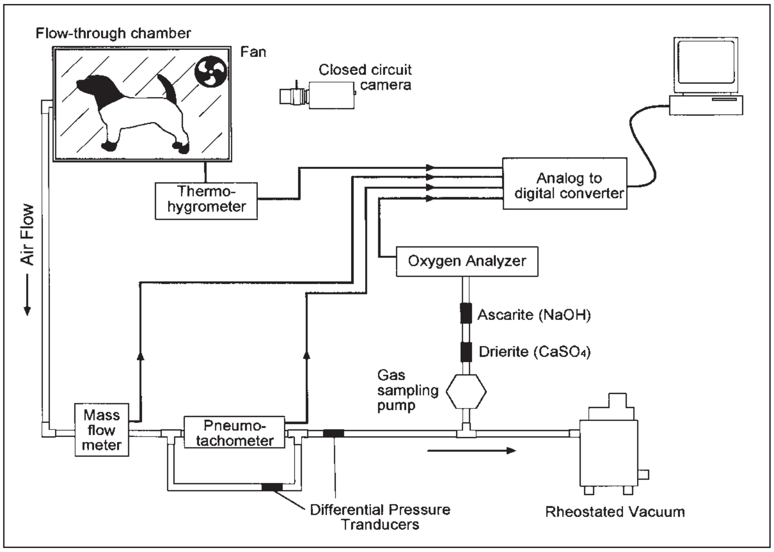

Figure 2—Schematic diagram of a flow-through indirect calorimeter used for measuring oxygen consumption of dogs while exposed to high or low ambient temperatures and while wearing or not wearing a spandex body garment.

analyzed for effects of ambient temperature and garment by means of split-plot ANOVA with standard software.[n] Values of $P \leq 0.05$ were considered significant.

Results

Two of the 12 dogs had to be removed from the study before completing all 4 experimental trials. One was a Labrador Retriever that developed myopathy; the other was a Beagle that developed aspergillosis.

In general, dogs appeared to tolerate wearing the garment. Experimental trials for the 10 dogs that completed the study were uncomplicated, with the exception that the Norwegian Elkhound appeared extremely agitated during its third experiment trial and was removed from the calorimeter chamber prematurely. The dog's rectal temperature when removed from the chamber was 43.1°C (109.6°F), which was 4.8°C (8.6°F) higher than when it was placed in the chamber. Data from this experimental trial were excluded from analyses, as steady-state $\dot{V}O_2$ was not achieved. The dog did pass a large volume of urine after it was removed from the calorimeter chamber, and it is possible that its agitation and transient hyperthermia were associated with stress because of a need to urinate. This trial was repeated without incident at another time, and those data were used for the analysis.

Mean ± SD ambient temperatures during low-temperature experimental trials were 21.5° ± 0.7°C (70.7 ± 1.3°F) when dogs were not wearing the garment and 21.2° ± 1.1°C (70.2° ± 2.0°F) when they were. Mean ambient temperatures during high-temperature experimental trials were 32.8° ± 1.0°C (91.0° ± 1.8°F) when dogs were not wearing the garment and 32.7° ± 0.5°C (90.9° ± 0.9°F) when they were. For all dogs, relative humidity in the calorimeter chamber exceeded 90% during the steady-state portion of all experimental trials.

Mean times that dogs stayed in the calorimeter chamber were not significantly different between low-temperature and high-temperature trials or between trials wearing the garment and trials not wearing the garment. Mean ± SD times in the chamber were 96.5 ± 30.6 minutes for low-temperature trials when dogs did not wear the garment, 94.6 ± 32.7 minutes for low-temperature trials when dogs did wear the garment, 109.1 ± 35.3 minutes for high-temperature trials when dogs did not wear the garment, and 101.3 ± 30.8 minutes for high-temperature trials when dogs did wear the garment.

Rectal temperature—Rectal temperature data were not normally distributed; therefore, they were log-transformed (after adding a constant to make all values positive) prior to analysis. Mean ± SD baseline rectal temperatures (ie, rectal temperatures before dogs were placed in the calorimeter chamber) were 38.1° ± 0.3°C (100.6° ± 0.5°F) for low-temperature trials when dogs did not wear the garment, 38.3° ± 0.1°C (100.9° ± 0.2°F) for low-temperature trials when dogs did wear the garment, 38.3° ± 0.2°C (100.9° ± 0.4°F) for high-temperature trials when dogs did not wear the garment, and 38.4° ± 0.2°C (101.1° ± 0.4°F) for high-temperature trials when dogs did wear the garment.

Overall mean change in rectal temperature while dogs were in the calorimeter chamber was 0.3° ± 0.8°C (0.5 ± 1.4°F). Mean change in rectal temperature during low-ambient temperature trials (–0.1° ± 0.4°C [–0.2° ± 0.7°F]) was significantly less than mean change during high-ambient temperature trials (0.7° ± 0.9°C [1.3° ± 1.6°F]). On the other hand, mean change in rectal temperature when dogs did not wear the garment (0.5° ± 0.9°C [0.9° ± 1.6°F]) was significantly greater than mean change when dogs did wear the garment (0.2° ± 0.7°C [0.4° ± 1.3°F]). The ANOVA indicated that individual dogs responded differently from each other.

Oxygen consumption—Data for specific O_2 consumption ($\dot{V}O_2$/kg) were not normally distributed; therefore, they were log-transformed prior to analysis. Overall mean specific O_2 consumption for all dogs during all trials was 0.149 ± 0.077 mL $O_2 \cdot s^{-1} \cdot kg^{-1}$. Specific O_2 consumption during low-ambient temperature trials (0.180 ± 0.095 mL $O_2 \cdot s^{-1} \cdot kg^{-1}$) was significantly higher than consumption during high-ambient temperature trials (0.118 ± 0.034 mL $O_2 \cdot s^{-1} \cdot kg^{-1}$). Specific O_2 consumption when dogs did not wear the garment (0.145 ± 0.059 mL $O_2 \cdot s^{-1} \cdot kg^{-1}$) was not significantly different from consumption when dogs did wear the garment (0.152 ± 0.093 mL $O_2 \cdot s^{-1} \cdot kg^{-1}$); however, the statistical power for this analysis was low (0.28).

Discussion

Like all homeotherms, dogs exchange heat with the environment through 3 mechanisms: radiation, conduction, and evaporation. If the sum of these exchanges is greater or less than the rate of metabolic heat production by metabolism, then the difference in heat energy is stored in or lost from the body, respectively, and body temperature increases or decreases accordingly.

We hypothesized that encasing a dog in a spandex garment would interfere with thermal conductance by trapping an insulating layer of air next to the body. As a result, we expected that rectal temperature would increase significantly when dogs wore the garment, particularly with a high ambient temperature. The ambient temperatures at which we conducted the experimental trials were chosen to bracket the expected thermoneutral zone for dogs,[4,5] as we thought that alterations in thermal conductance associated with the garment might shift the thermoneutral zone upward or downward and affect the amount of heat required from metabolism to maintain body temperature.

Not surprisingly, rectal temperature increased significantly more during high-ambient temperature trials than during low-ambient temperature trials in the present study. Unexpectedly, however, the mean rectal temperature increased when dogs did not wear the garment and was more than 2 times the mean increase when they did wear it. It seems possible, therefore, that the garment does not increase insulation or decrease thermal conductance in dogs, as would be expected in humans and as we had hypothesized, but rather actually increases thermal conductance by compressing the insulating fur. Because ambient temperatures in this study were less than rectal temperatures in the dogs, there should have been a net heat transfer from the dogs to the environment during both temperature treatments. Furthermore, because dogs rely on panting for evaporative heat loss, rather than cutaneous sweating as humans do, wearing a tight garment would not be expected to markedly decrease evaporative cooling in dogs as it might in humans.

Although there were no significant differences in time in the calorimeter chamber among experimental conditions, dogs were in the chamber nearly 10% longer during high-ambient temperature trials than during low-ambient temperature trials (105.2 ± 32.5 minutes vs 95.6 ± 33.5 minutes, respectively), and dogs were in the chamber nearly 5% longer when not wearing the garment than when wearing it (102.8 ± 32.8 minutes vs 98.0 ± 33.7 minutes, respectively). As both of these differences reflect the pattern of rectal temperature changes observed in the dogs, we cannot rule out that these small differences in exposure time contributed to the observed temperature changes. However, as the magnitudes of the relative exposure time differences are smaller than the magnitudes of the relative differences in rectal temperatures, exposure time would not appear to be the primary cause of the rectal temperature changes.

Mean specific O_2 consumption in these dogs (0.149 ± 0.077 mL $O_2 \bullet s^{-1} \bullet kg^{-1}$) was approximately 50% higher than that predicted allometrically[6] for a 17.5-kg (38.5-lb) mammal (0.098 mL $O_2 \bullet s^{-1} \bullet kg^{-1}$). This was considered a reasonably good agreement, given that dogs in this study were not being measured under standard conditions.

The only significant difference in specific O_2 consumption found in the present study was a 50% increase during low-ambient temperature trials, compared with high-ambient temperature trials. If the garment increased thermal conductances in these dogs and the dogs were at temperatures below their thermoneutral zones at an ambient temperature of 21.4°C, then we would have expected increased specific O_2 consumption as a result of thermogenesis to maintain body temperature. Given that rectal temperature decreased in the dogs during low-ambient temperature trials, this seems a reasonable explanation of the observed metabolic response.

Although the order of presentation for the garment variable (yes vs no) in the present study was randomized, the order of presentation of the ambient temperature variable was not; as for logistic reasons, we had to perform the low-ambient temperature trials before we could perform the high-ambient temperatures trials. A lack of randomization in the order of presentation of a variable is a violation of the assumptions for ANOVA, so we must be cautious in interpreting our results for ambient temperature. For this reason, we analyzed the data with a split-plot design, in which the main treatment effect of garment was modeled as subplots within plots (temperature) within blocks (dogs), so that the primary hypothesis tested by the model was whether the garment affected temperature homeostasis. We cannot rule out the possibility that what appeared to be temperature effects in the present study were actually a result of the order of presentation of the temperatures.

Results of the present study suggest that wearing a snug spandex body garment does not decrease thermal conductance in dogs or increase the possibility that dogs will overheat while in moderate ambient temperatures. Instead, wearing such a garment appeared to increase conductance and resulted in smaller increases in rectal temperature in warm environments. Dogs in this study were of different sizes and hair lengths, and ANOVA revealed significant differences in individual animal responses. A larger sample size would be required to determine whether breed, hair coat length, or body size affect the response to wearing a body garment. In addition, dogs were at rest in the present study when measurements were made, and effects may be different when dogs are active. Finally, only a single brand of body garment was used in the present study, and garments made of different materials such as fleece might have different effects. Results of this study do raise concerns as to whether dog garments might need to be insulated if dogs are to wear them in low ambient temperatures. Furthermore, it is important to recognize that insulation may be essential for protecting dogs from high conductive heat loads when wearing body garments in hot environments where ambient temperature exceeds rectal temperature.[7]

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[a] K9 TopCoat, TopCoat Inc, Talent, Ore.

[b] TT-45 digital thermocouple thermometer, Omega Engineering, Stamford, Conn.

[c] Intensive Care System-Plas Labs, Lansing, Mich.

[d] RH-70 digital thermohygrometer, Cole-Parmer Inc, Vernon Hills, Ill.

[e] Matheson 8219 mass-flow meter, Matheson Inc, Secaucus, NJ.

[f] Fleisch pneumotachometer, Hans Rudolph Co, Kansas City, Mo.

[g] Validyne MP5 differential pressure transducer, Validyne Corp, Northridge, Calif.

[h] Ametek R-2 diaphragm pump, Ametek Corp, Pittsburgh, Pa.

[i] Ametek S3-A/II oxygen analyzer, Ametek Corp, Pittsburgh, Pa.

[j] Drierite, W. A. Hammond Co, Xenia, Ohio.

[k] Ascarite, Thomas Scientific Co, Swedesboro, NC.

[l] Windaq 720-USB, Dataq Inc, Akron, Ohio.

[m] Windaq Pro+, Dataq Inc, Akron, Ohio.

[n] PROC ANOVA, version 8.2, SAS Institute Inc, Cary, NC.

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