ACKNOWLEDGMENTS

The authors gratefully acknowledge the efforts of Dr. Earl D. Folk and Mark H. George, Biostatistical Section, Civil Aeromedical Institute, for preparing the statistical data.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AM-87/3		

4. Title and Subtitle	5. Report Date
Tolerance by Unacclimated Beagle Dogs to Freezing and Subfreezing Temperatures	March 1987
	6. Performing Organization Code
7. Author(s): Gerald D. Hanneman and James L. Sershon	8. Performing Organization Report No.
9. Performing Organization Name and Address: FAA Civil Aeromedical Institute, P. O. Box 25082, Oklahoma City, OK 73125	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: Office of Aviation Medicine, Federal Aviation Administration, 800 Independence Avenue, SW., Washington, DC 20591	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes This work was performed under task AM-E-83-VM-1. Partial funding was provided by the United States Department of Agriculture under an FAA/USDA inter-agency cooperative agreement.

16. Abstract

Beagle dogs (3 and 6 months of age) unacclimated to cold air temperatures were exposed to temperatures near freezing (32 ^{o}F) or subfreezing (near 20 ^{o}F), while housed in simulated transport crates. All exposed dogs safely tolerated 4 hours of continuous cold exposure as evidenced by maintenance of rectal temperatures within an acceptable normal range. Heart rate, respiration rate, and behavior (barking and excessive movement) showed no deleterious change during exposure. No significant differences between males and females were found for rectal temperature, heart rate, and respiration rate. However, the males displayed more barking and excessive movement than females of the same age. The micro environment air temperature in the simulated transport crate was increased significantly (P. 0.001) by the presence of a dog during exposure to freezing temperatures. Results indicate that no harmful stress was encountered by the dogs exposed to 32 ^{o}F and 20 ^{o}F for 4 hours.

17. Key Words	18. Distribution Statement
Animals, dogs, animal physiology, environmental stress, cold stress.	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	15	

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TOLERANCE BY UNACCLIMATED BEAGLE DOGS TO FREEZING AND SUBFREEZING TEMPERATURES

INTRODUCTION

Current transportation standards for shipping dogs by commercial means, such as by commercial air carrier aircraft, state that the ambient air temperature surrounding a dog shall not be allowed to fall below 45°F; however, there is an exception: Dogs will be permitted to be transported or shipped from one point to another if accompanied by a certificate issued by an accredited licensed veterinarian, certifing that the animals in question are acclimated to air temperatures below 45°F.[1] In 1978, the United States Department of Agriculture (USDA) considered lowering the minimum air temperature limits for transporting dogs from 45°F to 35°F. Much controversy developed between humane groups, dog owners, handlers, and shippers. At that time, sufficent scientific evidence was not introduced to show that dogs would not be harmed by colder temperatures during the transport period; thus, the standards remained unchanged. Many dogs throughout the United States live out-of-doors during cold winter months and remain healthy at temperatures well below 45°F. Dogs are also raised indoors during the winter and are exposed to the out-of-door elements for only short periods. These indoor raised-animals are the primary subject of concern. Long haired, well insulated dogs, such as the Husky, tolerate extremely cold weather with no harm to body physiology.[2] Of greater concern were the effects of such exposure on the short-haired, less well insulated dogs, such as the beagle. Spealman[3] reported some dogs were able to maintain a normal body temperature for five hours when immersed up to the level of the neck in 32°F water. Durrer and Hannon[2] subjected indoor-housed beagles to out-of-door temperatures between -4 to +14°F for 5 hours daily, and later 12 hours daily. The only undesirable responses reported were some evidence of mild frostbite on the feet from the snow and violent shivering on initial exposures. Gradually the intensity of shivering decreased and the cold injuries were transient.

In the cargo compartment of commercial air carrier aircraft, where dogs would be stowed during transport, the ambient air temperature has been reported to be as low as 32°F with ice forming in the compartment.

In an effort to better define the effects of freezing and subfreezing air temperatures on short haired dogs, the FAA, under a cooperative interagency agreement with the USDA, offered to investigate cold temperature responses on unacclimated beagle dogs.

METHODS AND MATERIALS

Thirty healthy unacclimated beagle dogs were used in three cold temperature experiments, using 10 dogs per experimental condition. The cold temperature environment was provided by an environmental chamber (10'H X 10'L X 8'W) at the Civil Aeromedical Institute. The first test environment (32°F) was studied with 10 male dogs, 6 months of age, weighing between 19 and 22 pounds. In each of the second and third experiments (at 32°F and 20°F, respectively) 10 3-month old dogs were used (5 females and 5 males each, weighing between 8 and 12 pounds). All dogs came from the same purebred colony of research animals, many of which were litter mates. They were maintained on a diet of Purina Puppy Chow and/or Hill's P/d® canned dog food, depending on their arrival weight.

Testing order was determined by body weight, with the heavier dogs tested first. None of the animals received any form of medication for at least 7 days prior to the experiments. The dogs were tested individually in a simulated shipping crate (30"L X 18"W X 22"H) constructed of clear plastic material; this permitted observation of the dogs at all times (Figure 1). The ventilatory openings, prescribed by regulations, were

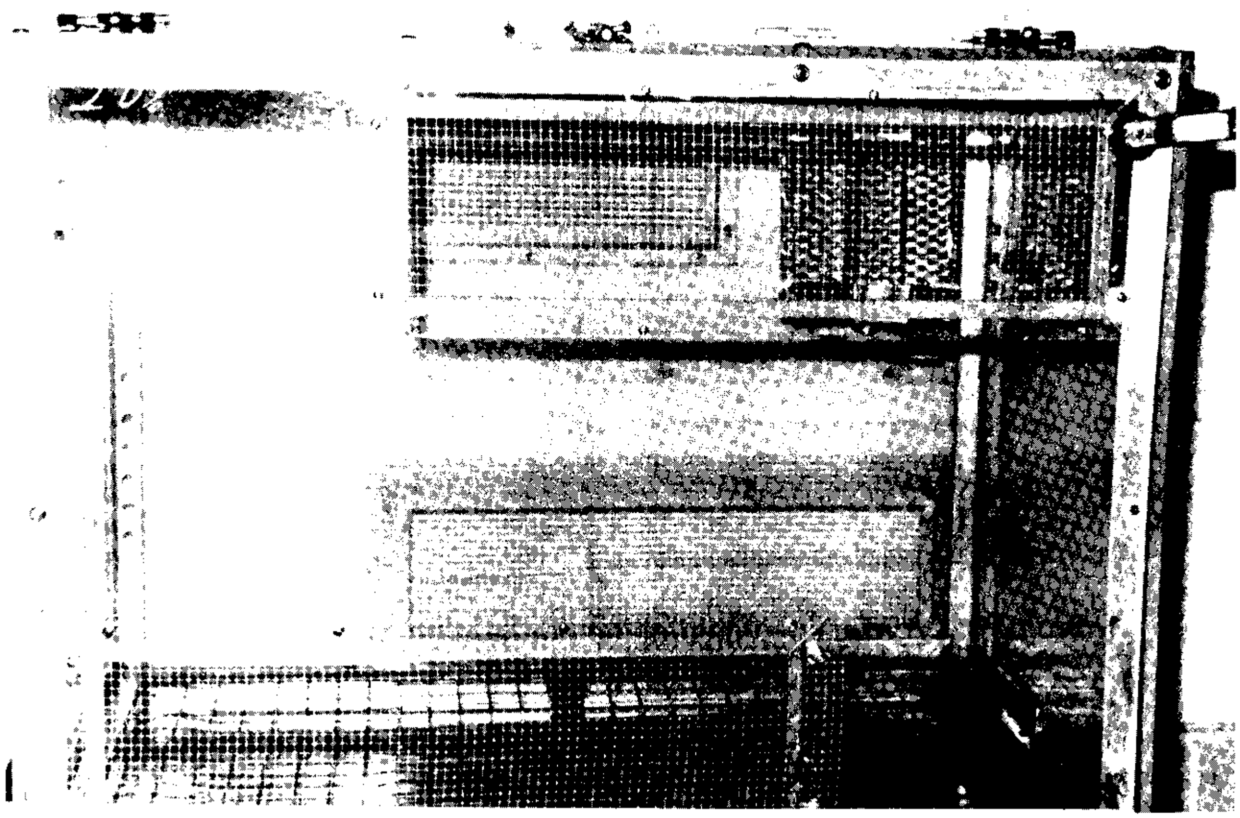

Figure 1. Simulated shipping crate used for exposing beagle dogs to cold environments (30"L X 18"W X 22"H). Each of the two parallel long sides provides 16 percent openness. The two parallel short ends are not open for ventilation. Total openness of the crate (considering all four sides) equals 14 percent ventilation.

provided in the two parallel long sides of the crate.[4] Four days before cold testing each dog was fitted with a wire face muzzle which served to prevent chewing on equipment during testing. The dogs were also conditioned to a crate similar to one used during testing.

Dogs were fed 4 ounces of P/d® dog food the morning of testing; dogs were normally fed at 8:00 a.m. daily. Thirty minutes after feeding they were weighed, prepared for the test, placed in a test crate identical to the cold exposure crate, and transferred to the test chamber area.

In the room outside the environmental test chamber, baseline data were obtained on the dogs for rectal temperature (Tre), heart rate (HR), respiration rate (RR), and behavior (barking and excessive movement) for 45 minutes. At the same time, air temperature and humidity were monitored for the test crate inside the cold chamber to determine the crate's micro-environment with dog absent. Starting at 10:00 a.m. regularly, dogs were hand-carried into the environmental chamber and placed in the pre-chilled test crate. During cold exposure the dogs continued to be monitored for the Tre, HR, and RR using noninvasive methods (Figure 2).[5] Both barking and excessive movement were

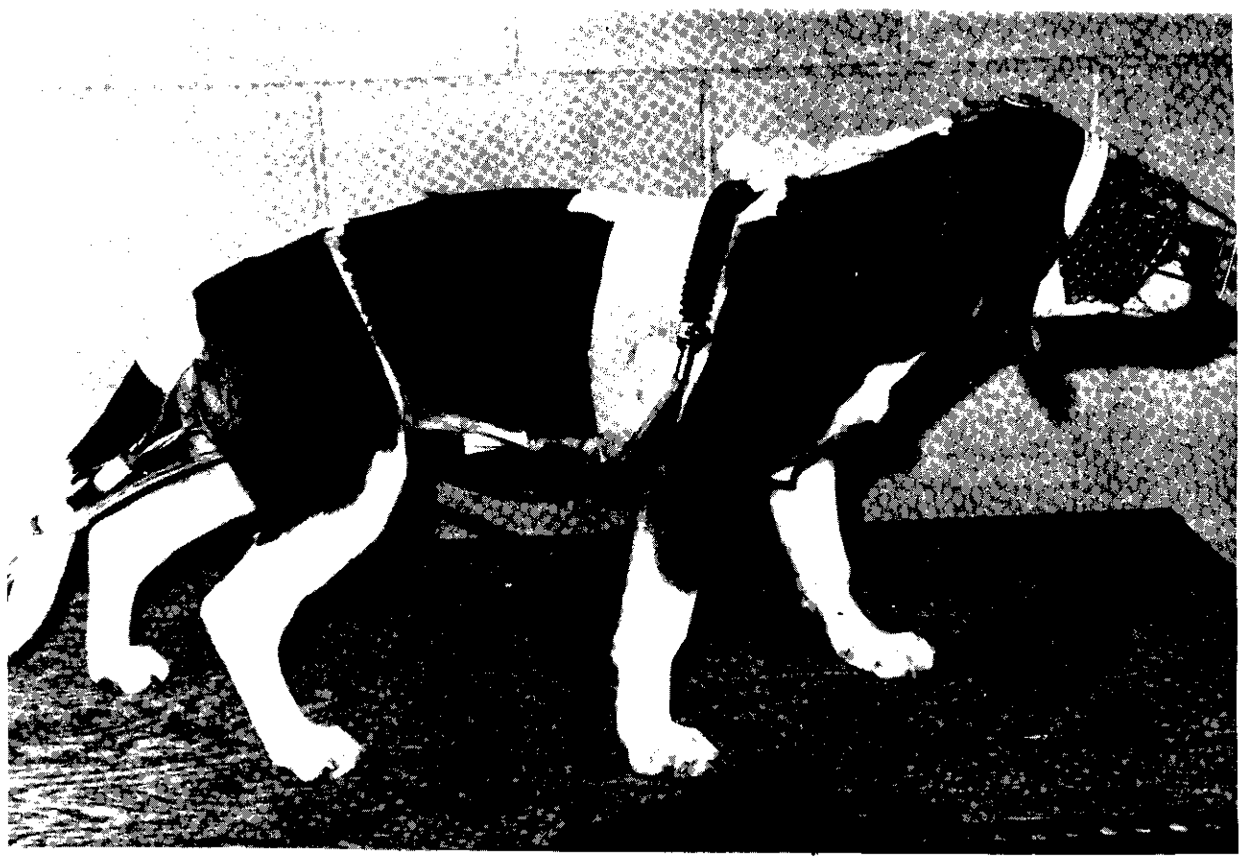

Figure 2. Shows dog prepared for monitoring rectal temperature, heart rate, and respiration rate. Dogs were able to move about freely inside test crate during exposure to cold air temperature.

monitored continuously, barking by means of an intercom while excessive movement was observed visually through a window in the lighted chamber. After 4 hours of continuous exposure to the cold environment the dogs were removed from the chamber and returned to their living quarters where the monitoring equipment was removed. After 30 minutes of observation they were placed in their cages, given water, and observed for any evidence of sequela for 7 days.

RESULTS

Although change occurred in several physiological parameters measured, all dogs studied safely tolerated 4 hours of continous exposure to either freezing or subfreezing air temperatures. No ill effects from the extreme cold were observed during testing or during 7 subsequent days.

To simplify identifying the dogs in reporting results in the following tables, the 6-month-old dogs exposed to near 32°F will be referred to as group A, the 3-month-old dogs at near 32°F as group B, and the 3-month-old dogs at near 20°F as group C.

Table 1 shows each group's mean rectal temperature before, and in response to, cold exposure. Group A and B had mean decrease compared to an increase

TABLE 1. - Rectal Temperature of Beagle Dogs During Cold Exposure

Dog Group*	Mean Rectal Temperature (°F)			
	Start	End	Change	4 Hour Average
A	101.9	101.4	Decrease 0.5	101.7
B	101.3	101.0	Decrease 0.3	101.2
C	101.2	101.5	Increase 0.3	101.4

*10 dogs in each group.

for group C. Only one dog from group A finished 4 hours of exposure with a rectal temperature higher than its starting value compared to three from group B and six from group C. Three dogs each from group A and group B, and seven dogs from group C, had a 4-hour mean rectal temperature higher than their starting values. The paired t-test failed to show a statistically significant difference between pretest rectal temperature values and results after 4 hours of cold exposure for groups A, B, and C.

Average change in heart rate between baseline and the 4 hour cold exposure values for groups A, B, and C are shown in Table 2. A significant

TABLE 2. - Heart Rate
(Baseline vs Cold Exposure)

Dog Group	Beats Per Minute (Average)		
	Baseline*	Cold Exposure**	Increase
A	117	134	+17
B	153	181	+23
C	137	207	+70

*Average of 10 readings (5 minute intervals)
**Average of 48 readings (5 minute intervals)

increase in mean heart rate occurred during cold exposure for group A ($t= -3.10$, $P<0.05$), B ($t= -4.45$, $P<0.01$), and C ($t= -11.76$, $P<0.001$). Only one dog (from group A) had a cold exposure value lower than its baseline. The increase in heart rate was not unexpected. Increased heart rates may be related to the increased metabolic rate brought about by shivering and activity.

Table 3 shows the average respiration rates for groups A, B, and C during baseline and 4 hours of cold exposure. One dog from group A and three from

TABLE 3. - Respiration Rate
(Baseline vs Cold Exposure)

Dog Group	Rate Per Minute (Average)		
	Baseline*	Cold Exposure**	Decrease
A	47	29	-18
B	57	47	-10
C	39	32	-7

* Average of 10 readings (5 minute intervals)
** Average of 48 readings (5 minute intervals)

groups B and C, experienced an increase in respiration rate; however, the average respiration rate for each group decreased during cold exposure. The change in mean respiration rate values between baseline and cold exposure was statistically significant for only groups A ($t=3.87$, $P<0.001$) and C ($t=2.53$, $P<0.05$). Were it not for variations in group B dogs' baseline respiration rates, they may also have shown a significant decrease. Although a decrease in respiration rate was shown (baseline versus cold exposure), this decrease is not critical for the dogs, since all were within acceptable limits for anxious dogs.

Prior to entering the cold chamber, the dogs were generally quiet and calm with only minimal barking and excessive movement; however, when introduced into the cold chamber, many dogs would begin barking and displaying excessive movements, such as pawing at the crate walls, crawling around on the crate floor, and rolling. Behavorial activity was monitored during testing and recorded at 5 minute increments. This behavorial activity, shown in Table 4, compares the average number of 5-minute increment periods and time (in minutes) spent by dogs in each group that displayed this behavior.

TABLE 4. - Comparison of Behaviorial Activity Between Groups A, B, and C Dogs During Cold Exposure

Dog Group	Barking (Average)			Excessive Movements (Average)		
	Dogs (No.)	Periods* (No.)	Time (Min.)	Dogs (No.)	Periods* (No.)	Time (Min.)
A	5	7.6	9.4	7	3.0	3.1
B	9	9.5	25.3	10	9.0	18.8
C	10	12.4	22.4	9	13.4	20.1

*There were a total of 48 (5 Min.) Periods during cold exposure.

Dogs in the younger groups (B and C) spent more time barking and displayed excessive movement more often than the older group A dogs. While in the cold chamber, 5 dogs from group A never barked and 3 dogs displayed no excessive movement. Group C dogs, exposed to the coldest temperatures, displayed barking and excessive movement during about one-fourth of the total number of 5 minute periods.

Because both males and females were used in groups B and C, we wanted to determine if any of the responses may be sex related. Table 5 shows a comparison between males' and females' rectal temperatures, heart rates, and respiration rates during cold exposure. Although a notable difference in re-

TABLE 5. - Average Rectal Temperatures, Heart Rates, and Respiration Rates for Groups B and C Dogs* (Males vs Females)

	Rectal Temperatures (°F)		Heart Rate (BPM)		Respiration Rate (RPM)	
Dogs	B	C	B	C	B	C
Males	101.3	101.4	179	206	48	31
Females	101.0	101.4	183	208	36	32

*Each group (B and C) has 5 males and 5 females.

spiration rate was shown between males and females of group B, statistically there was no significant difference between males and females for rectal temperatures, heart rates, or respiration rates in either group B or C. The most observable difference between males and females during cold exposure was in behavior. The increased barking and excessive movement demonstrated by the male dogs was nearly twice that of the females for both groups B and C (Table 6); however, these behavorial differences seen between the males

TABLE 6. - Behavior Comparision Between Group A and B Males and Females During 4 Hours Cold Exposure*

	Barking (Ave.)				Excessive Movements (Ave.)			
	Periods (No.)		Time (Min.)		Periods (No.)		Time (Min.)	
Dogs	B	C	B	C	B	C	B	C
Males	11.8	16.0	29.6	36.1	10.6	15.4	23.3	25.7
Females	5.4	8.8	10.8	8.6	7.4	8.8	14.3	10.2

*Each group (B and C) had 5 males and 5 females. There were a total of 48 (5 minute) periods during cold exposure.

and females were found not to be statistically significant for either group B or C. Two factors may have contributed to no significant differences being found: One, the numbers of males and females in each group were small; and two, there was considerable difference in the amount of barking and excessive movement displayed by individual animals. Increased activity during exposure to cold temperatures could be advantageous for dogs, as metabolic heat would increase.

When the dogs were placed in the cold chamber exposure crate, the crate's internal air temperature would increase (Table 7). For dogs exposes to near

TABLE 7. - Change in Air Temperature Inside Exposure Crate (Baseline vs Testing)

Dog Group	Air Temperature Inside Crate (°F)		
	Baseline* (No Dog in Crate)	Testing** (Dog in Crate)	Increase
A	31.4	38.4	7.0
B	31.7	36.2	4.5
C	19.9	25.4	5.5

*Average of 10 readings taken at 5 minute intervals.
**Average of 48 readings taken at 5 minute intervals.

32°F, this increase in internal crate temperature was shown to be greater for the older (group A) dogs than for the younger (group B) dogs. It is reasonable to expect that the older dogs contributed more heat input to their crates' internal environment than did the younger dogs as evidenced by their higher decrease in rectal temperature. In comparing the two younger (3-month-old) groups of dogs (B and C), results show the group C dogs exposed to the subfreezing (20°F) temperature contributed more heat to their environment than the warmer (32°F) exposed group B dogs; no doubt more metabolic heat was being generated by the colder exposed group C dogs as they showed more increased activity, faster heart rates, and less decrease in respiration rates while maintaining their rectal temperatures above pre-exposure values. The differences between pretest (no dog in crate) and cold test (dog in crate) crate mean air temperatures were shown to be statistically significant ($P<0.001$) for groups A, B, and C.

DISCUSSION

When unacclimated dogs are exposed to cold air temperatures, events take place to conserve body heat and prevent a drop in body temperature to dangerous levels. Dogs will make postural changes by lying down in a curled-up position. The skin's cold receptors are stimulated causing the body hair or fur to erect, which further provides effective insulation.[6] Cutaneous vasoconstriction occurs, reducing heat loss between the skin and the environment.[7] As vasoconstriction develops, the surface temperature of the back, tail, and foot pads will lower and heart rate will increase.[8] In our studies, only 1 out of 30 dogs had a 4-hour average heart rate lower than its baseline value.

Shivering is a very important response to cold exposure and a major contributor to body heat production. All our dogs experienced shivering, but we were unable to determine exactly when it began, because the dogs were moving about the crate during the early stages of exposure. Shivering increases oxygen consumption, muscular activity, and metabolic rate.[9] Dogs have been reported to show a 3-to-4-fold increase in metabolism when shivering.[10] Jensen and Ederstrom report that as a dog matures, shivering becomes increasingly more powerful and sustained.[8] An animal exposed to the cold will not necessarily experience a lowering of body temperature as shivering occurs.[2] Large dogs are reported to cool more slowly than smaller dogs because they have less surface area per unit of body mass.[3]

When dogs are exposed to cold temperatures, respiration rates are reported to increase.[10] However, at the temperatures to which our dogs were exposed, average 4-hour respiration rates for 23 of 30 dogs were decreased from baseline values.

Two factors may have contributed to the lower respiration rates seen during cold exposures. First, baseline respiration rates were on the high side of normal to begin with, as many dogs were quite anxious during the time period before baseline data was monitored. Secondly, it is reasonable to suspect that because the dogs were being exposed to such cold temperatures for the first time, their body efforts were being concentrated on conserving body heat through shivering and that respirations became deeper and less frequent.

The dogs in our study were able to maintain rectal temperatures very close to their baseline values during 4 hours of cold exposure. The two 3-month-old groups (B and C) were possibly a little more successful than the 6-month-old dogs because of their increased activity. In addition, the group C dogs showed a considerable increase in heart rate during cold exposure. During short periods of increased activity, rectal temperatures would rise as much as 0.5°F, but as activity subsided, rectal temperatures would lower to pre-activity levels. If the dogs had lain quietly without any activity, one would have expected rectal temperatures to have been somewhat lower than shown. Moderate periodic increases in activity during cold exposure would appear beneficial in assisting dogs in maintaining a level body temperature, whereas increased activity in a hot environment would be disadvantageous to dogs. In either situation, increased activity to the point of exhaustion would be detrimental. Data providing a baseline activity level during 4 hours of confinement while in a more nominal temperature (e.g. 70°F) are not available for comparision.

Our study indicates that in cold weather, if dogs were housed in a shipping crate having 14 percent or less ventilated area, the temperature of the crates' micro-environment would be increased and maintained over the outside-of-the crate air temperature. The crate would need to be located in areas where air flow (wind) was at a low velocity. If the crate were positioned such that an increased air flow were passing through the crate openings, then the wind chill factor would adversely affect the dogs. The fact that the same size crate was used for both the 6-month-old and 3-month-old dogs may account for some of the in-crate temperature increase of the older dogs. Typically, however, the same sized crate is often used to transport dogs of different sizes. It is also expected that the larger dogs would contribute more heat to the crate environment, since they do have more body mass exposed to the environment. McIntyre et al[11] reported that cold exposure metabolic heat production in the young dog is very similar to that of the adult. Thus, it is unlikely there was a significant difference in metabolic heat production between the two age groups. Once the dogs were removed from the cold environments, shivering stopped almost immediately, and from all appearances they were essentially the same as prior to cold exposure.

SUMMARY

We found that healthy beagle dogs (3 and 6 months of age), confined in a crate having a 14-percent ventilation area, can safely tolerate 4 hours of continuous exposure to freezing and subfreezing temperatures. None of the animals in our study showed any post-exposure sequela during the 7-day observation period. All dogs maintained a rectal temperature in the expected normal range. Heart rates usually increased during cold exposure, while respiration rates decreased for most dogs. Barking and excessive movement increased, but this is partly anticipated when dogs are introduced into unusually cold environments and isolated from human contact. However, these activities subsided as the dogs became more familiar with the new cold environment.

Three-month-old male and female beagle dogs exposed to cold temperatures showed few differences in rectal temperature, heart rate, and respiration rate. However, the 3-month-old males did display more barking and activity than did their female counterparts.

Placing a dog inside a pre-chilled transport crate caused a rise in in-crate ambient air temperature. This in-crate temperature increase was maintained throughout the exposure period, during which time the outside-crate air temperature was held fixed. This response was indicative of the satisfactory compensatory heat production experienced by the dogs. As far as the dogs were concerned, they were experiencing the effects of the created warmer temperatures, rather than colder chamber temperatures.

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*U.S. GOVERNMENT PRINTING OFFICE: 1987-722-151 Region 4.