TECHNICAL CONTRIBUTION

THE EFFECT OF TRANSPORT ON CORE AND PERIPHERAL BODY TEMPERATURES AND HEART RATE OF SHEEP

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Abstract

*The effect of transport on core and peripheral body temperatures and heart rate was assessed in ten 18-month-old Coopworth ewes (*Ovis aries*). Manual recordings of core (rectal) temperatures were obtained, and automated logging of peripheral (external auditory canal and pinna) temperatures and heart rate was carried out on the day prior to (day 1) and during (day 2) a standardised transport procedure. Transport produced a significant increase in the rectal temperature, which declined following unloading. Peripheral measures of body temperature also exhibited changes with transport. However, both ear-canal and pinna temperatures declined during actual transport, reflecting to some extent the decline in ambient temperatures recorded externally by sensors on the ear tags of the animals. Peripheral measurement of temperature, particularly at the readily accessible ear canal, may offer potential as a technique for the long-term monitoring of thermal responses to stress. However, further research is required into the potentially confounding effects of ambient temperature and wind chill factors.*

Keywords: *animal welfare, body temperature, heart rate, sheep, transport*

Introduction

A variety of physiological and behavioural indices have been used to evaluate or quantify an animal's response to stress (Broom 1988). An increase in core body temperature in response to stress has been reported in various species, including rats (Nakamori *et al* 1993), mice (Borsini *et al* 1989; Cabanac & Briese 1992), rabbits (Snow & Horita 1982), pigs (Parrott & Lloyd 1995) and man (Marazziti *et al* 1992). Recently, changes in core body temperature have been used in sheep to assess the stressfulness of management procedures such as transport, exercise, and the presence of a dog (Parrott *et al* 1999). It is postulated that stress-induced hyperthermia is primarily a prostaglandin-dependent mechanism similar to fever, as inhibitors of prostaglandin can block the response (Singer *et al* 1986; Morimoto *et al* 1987; Kluger *et al* 1987; Parrott & Lloyd 1995).

As a potential index of stress, temperature readily lends itself to long-term automated monitoring. However, measurement of core body temperature involves either surgical implantation of biotelemetry equipment (Parrott *et al* 1999) or the use of relatively invasive rectal or vaginal probes. The use of peripheral sites for recording temperature has the advantage that these sites are more readily accessible and the invasive load upon the animal is, therefore, likely to be smaller. Little is known about the peripheral temperature changes in response to stress in sheep; hence, the aim of this experiment was to investigate the effects of a transport stressor on peripheral body temperatures. Heart-rate responses, manually collected rectal temperature measurements and automatically recorded temperature readings from the external auditory canal and pinna were analysed.

Materials and methods

Animals

The use of animals in this study was approved by the Ruakura Animal Ethics Committee. The animals were ten 18-month-old Coopworth ewes (*Ovis aries*) (15.2 ± 0.4 kg carcass weight) maintained at the Ruakura Agricultural Centre, Hamilton, New Zealand (37°46'S, 175°20'E) in outdoor paddocks with *ad libitum* access to pasture (ryegrass–white clover) and water. The sheep had all been previously used in a five-week study investigating heart-rate responses to stress, and thus were well accustomed to being handled and wearing the recording equipment used in the present study.

Recording equipment

Animals were equipped during the study with a Free-Range Physiological Monitor (FRPM, HortResearch, Hamilton NZ) and two temperature-logging ear tags (Temptag, HortResearch, Hamilton, NZ). The FRPM is a recently developed instrumentation pack designed to record and analyse physiological signals, such as the ECG, from freely behaving animals (Harris 1999). It incorporates a microprocessor and 10 MB of memory storage enclosed in an aluminium case (260 x 120 x 30 mm), weighing a total of 980 g. The FRPM is attached with the aid of a Velcro patch (105 x 250 mm) glued to the animal's back and secured with an elasticised girth strap. ECG recordings are obtained from three (positive, negative and ground) Ag/AgCl surface electrodes (Red Dot, 3M Health Care, USA) positioned on the animal's body.

The temperature-logging ear tags have also recently been developed by our group for long-term monitoring of temperature in freely behaving animals. These tags can record 2000 measurements from each of two temperature sensors, with an accuracy of 0.1°C and a resolution of 0.05°C, and can be programmed to record at different time intervals (ranging between four seconds and several hours). The loggers were enclosed in a circular plastic case (diameter 45 mm, width 8 mm) glued to an ear tag (Allflex New Zealand Ltd, Palmerston North, NZ), and weighed 17 g in total. The ear tag was used to attach the logger to the ear through existing ear-tag holes. For this experiment, the sensor for one of the temperature channels was connected to the logger by a flexible wire. This allowed the sensor to be glued directly onto the under-surface of the ear in order to measure the pinna temperature, or to be incorporated into a foam outer-ear-canal plug (Pura-fit 6800, Moldex-Metric Inc, Culver City CA, USA) and used to measure external auditory canal temperature. Ambient temperatures were obtained from a sensor located within the logger case attached to the ear tag of each animal. Rectal temperatures were obtained manually using a flexible digital thermometer (Becton Dickinson, Canada).

Procedure

On the day prior to the start of the trial, all animals were herded into pens in the yard ('yarded') and weighed. The three ECG electrode sites were clipped and degreased with ethanol, and the electrodes were fixed to the skin with cyanoacrylate glue (Loctite 454 gel, Loctite Australia Pty Ltd, NSW, Australia). The positive and negative electrodes were situated on the left side of the animal, over the axilla region and immediately posterior to the scapula, respectively. The ground electrode was situated on the right side of the animal, over the middle of the rib cage, lateral to the midline of the back.

On day 1, all animals were yarded (0700h) and equipped with a FRPM and two temperature-logging ear tags (pinna and ear-canal configurations). The FRPM was programmed to record a continuous ECG for a 3 min period every 5 min, while the temperature-logging ear tags were programmed to take a temperature reading every 3.6 min. Following attachment of the equipment, a rectal temperature reading was taken manually using a digital thermometer. All animals were then returned to their paddock (at 0816h) and left undisturbed until 1500h. On completion of this monitoring period, all animals were returned to the yards, a rectal temperature reading was taken and the FRPM and temperature loggers removed for downloading of the data. All animals were then returned to pasture overnight.

On the following day (day 2), all the animals were brought into the yard (at 0700h) and the equipment was attached as on day 1. A rectal temperature reading was obtained (at approximately 0730h) and the group was released back to pasture (0805h) to recover from the effects of handling. At 0830h, the animals were again brought into the yard and a second rectal temperature measurement obtained (at approximately 0845h). The animals were then loaded into an open livestock trailer (pen size 1.3 x 2.4 m) between 0850h and 0855h. After loading, the animals were driven on the open road for 25 min before stopping for 10 min to obtain a third rectal temperature reading (at approximately 0927h) while the animals remained on the trailer. The animals were then driven on the open road for a further 25 min before being unloaded at a handling facility unfamiliar to the sheep. During the transportation periods, the van towing the livestock trailer did not exceed 90 km h^{-1}. Following unloading, the animals were placed in a pen and a fourth rectal temperature reading was obtained (at approximately 1020h). The animals were left undisturbed until the end of the monitoring period (1040h). On completion of the monitoring period, a fifth and final rectal temperature reading was taken (at approximately 1052h) and the FRPM and temperature loggers removed for downloading of the recorded data.

Statistical analyses

All data are represented as means ± the standard error of the mean (SEM). Heart rate was determined by calculating the average pulse interval for each 3 min period of ECG recording using a peak-detection algorithm developed in-house.

Rectal temperature (RT) values obtained during the attachment of equipment on the morning of day 2, and the mean external auditory canal temperature (CT), ear pinna temperature (PT), ambient temperature (AT) and heart rate (HR) values obtained during the corresponding time period at pasture on day 1, were taken as basal readings. The difference between basal values and the mean values obtained during different phases of the transport procedure were calculated for each individual. Statistical comparisons of these net differences were made using the Student's *t*-distribution (Excel, Microsoft, USA).

Results

The RT response of the sheep (n = 10) to the transport procedure is shown in Figure 1. On day 1, RT values were similar during the attachment of equipment in the morning (39.34 ± 0.13°C) and the removal of equipment in the afternoon (39.56 ± 0.09°C; not shown in Figure 1). RT values obtained during the attachment of equipment in the morning of day 2 (39.14 ± 0.15°C) were also similar to values obtained at the corresponding time on day 1. On day 2, RT values obtained during the yarding immediately prior to transport (39.13 ± 0.15°C) were also similar to day 2 baseline values. However, RT values increased significantly ($P < 0.001$) above baseline during transport (0.55 ± 0.11°C), and remained significantly ($P < 0.010$) elevated following unloading (0.41 ± 0.11°C). RT values declined significantly ($P < 0.050$) from initial unloading values following holding in unfamiliar yards, although RT values still tended ($P = 0.069$) to be higher (0.26 ± 0.13°C) than pre-transport baseline levels.

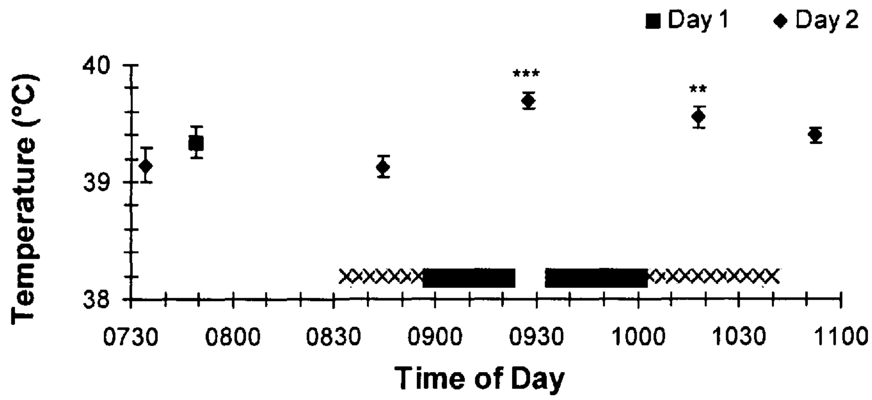

Figure 1 **The response of rectal temperature to yarding, transport and holding in unfamiliar pens. The grey hatched bars at the bottom of the graph represent the period of time in the yards, whereas the black bars represent the two periods of transport separated by a 10 min stop for collection of rectal temperatures. Points with superscripts are significantly different (*$P < 0.05$, **$P < 0.001$, ***$P < 0.0001$) from pre-transport values (0844h, day 2).**

Ear canal temperature (CT), ear pinna temperature (PT) and ambient temperature (AT) recordings obtained using the temperature-logging ear tags are shown in Figure 2. CT, PT and AT profiles were successfully collected over both days 1 and 2 from seven, eight and nine of the 10 sheep, respectively. On day 1, CT, PT and AT values averaged 37.01 ± 0.33°C, 34.73 ± 0.27°C and 15.75 ± 0.80°C, respectively. The mean differences between each phase of the transport procedure and the corresponding time period on day 1 (baseline values) for CT, PT and AT referred to in the following text are shown in Table 1. On the morning of day 2, CT values obtained at pasture were significantly higher ($P < 0.050$), whereas PT values were similar ($P > 0.050$) to the corresponding day 1 baseline levels. Yarding and the subsequent loading process produced a significant ($P < 0.010$) increase in CT but had no significant effect on PT values. However, transportation resulted in a rapid decline in both CT and PT to temperatures that were significantly ($P < 0.050$) below baseline levels. Both CT and PT values began to rise prior to the end of the transport phase, although PT levels were still significantly below their baseline values. During the stationary phase required for manual sampling of RT, both CT and PT values increased, with PT being similar to and CT significantly elevated above baseline levels. A similar pattern of CT and PT changes was observed during the second transport period. During unloading and holding in an unfamiliar pen, only CT values increased significantly above baseline, whereas PT values remained at values similar to baseline.

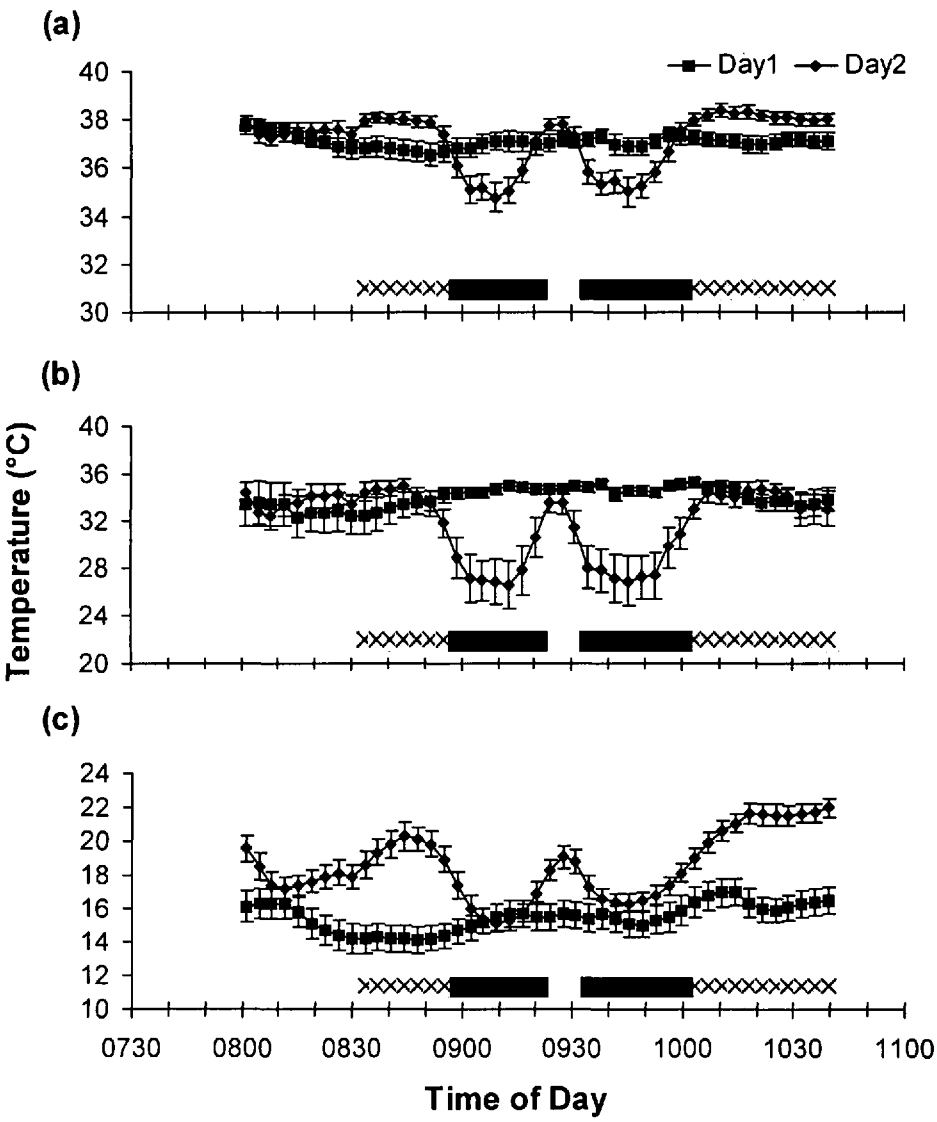

Figure 2 **Temperature responses of (a) the ear canal and (b) the pinna of sheep at pasture (day 1) and during transport (day 2). (c) Ambient temperatures recorded on the ear tags of the animals. The grey hatched bars at the bottom of the graph represent the period of time in the yards, whereas the black bars represent the two periods of transport separated by a 10 min stop.**

Transport on day 2 produced changes in AT that followed similar patterns to those seen for both CT and PT. On day 2, however, ambient temperatures were generally higher than on day 1, mainly because of warmer weather conditions. This resulted in AT values for day 2 being significantly ($P < 0.050$) higher than day 1 baseline values for all stages of the transport procedure except for the trough in AT during the first transport phase, where AT values declined to levels similar to those of day 1 baseline values.

Table 1 **Mean changes from day 1 baseline temperatures (ΔT [°C]) averaged over the relevant time periods recorded during different stages of the transport treatment on day 2. Values with superscripts are significantly different (*$P < 0.05$, **$P < 0.001$, ***$P < 0.0001$) from the corresponding day 1 values.**

Treatment	ΔT Ear Canal	ΔT Pinna	ΔT Ambient
Paddock (0815h–0830h day 1) (0805h–0830h day 2)	$0.54 \pm 0.14^{*}$	0.00 ± 0.90	$3.15 \pm 0.21^{***}$
Yard (0831h–0850h)	$1.22 \pm 0.26^{**}$	0.73 ± 0.58	$5.44 \pm 0.33^{***}$
Load (0851h–0854h)	$1.33 \pm 0.31^{**}$	-0.50 ± 0.98	$5.67 \pm 0.36^{***}$
Start of Transport 1 (0855h–0900h)	-0.04 ± 0.39	$-3.60 \pm 1.51^{*}$	$3.69 \pm 0.53^{***}$
Transport 1 (0901h–0915h)	$-1.98 \pm 0.36^{**}$	$-7.09 \pm 1.80^{**}$	0.05 ± 0.41
End of Transport 1 (0916h–0920h)	-0.53 ± 0.36	$-4.74 \pm 1.76^{*}$	0.54 ± 0.53
Stop (0921h–0931h)	$0.51 \pm 0.14^{**}$	-1.25 ± 0.81	$3.12 \pm 0.36^{***}$
Start of Transport 2 (0932h–0940h)	$-1.66 \pm 0.26^{***}$	$-6.53 \pm 1.75^{**}$	$1.31 \pm 0.38^{**}$
Transport 2 (0941h–0955h)	$-1.57 \pm 0.26^{***}$	$-6.34 \pm 1.79^{**}$	$1.17 \pm 0.43^{*}$
End of Transport 2 (0956h–1000h)	-0.24 ± 0.23	$-3.82 \pm 1.17^{*}$	$1.92 \pm 0.54^{**}$
Unload (1001h–1005h)	$0.73 \pm 0.11^{***}$	-2.05 ± 0.94	$2.48 \pm 0.58^{**}$
Unfamiliar Pen (1006h–1040h)	$1.05 \pm 0.18^{**}$	-0.08 ± 0.56	$4.82 \pm 0.38^{***}$

The mean heart rates (HR) of sheep at pasture on day 1 (baseline) and during the transport procedure on day 2 are shown in Figure 3. The mean differences in HR between each phase of the transport procedure and the corresponding day 1 baseline values referred to in the following text are shown in Table 2. On day 1, HR values from animals at pasture (baseline) averaged 102.6 ± 5.3 beats min^{-1}. On both days 1 and 2, HR values obtained in the yards prior to release were similar (85.5 ± 12.2 and 84.3 ± 5.4, respectively). On day 2, HR when compared with day 1 baseline values was significantly ($P < 0.010$) lower during the yarding immediately prior to transport and significantly ($P < 0.010$) higher during unloading. At all other phases of the day 2 transport procedure, HR was similar to the corresponding baseline values on day 1. Visual inspection of the individual data (not shown) revealed consistent patterns in HR during the transport procedure on day 2. All animals exhibited a decline in HR with yarding and an increase with loading. The response to actual transportation was more variable, with some animals exhibiting increases and others showing decreases at different stages of the trip. Unloading produced a transient increase in HR, which then declined in most animals during holding in an unfamiliar pen.

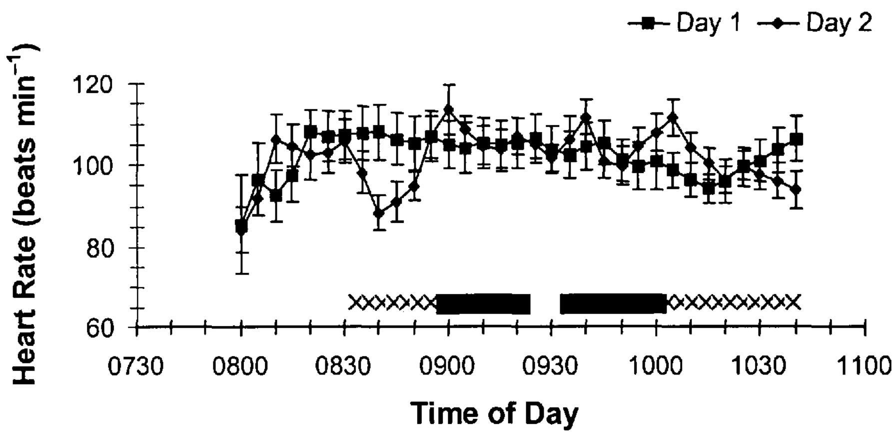

Figure 3 Heart rate responses of sheep at pasture (day 1) and during transport (day 2). The grey bars at the bottom of the graph represent the period of time in the yards, whereas the black bars represent the two periods of transport separated by a 10 min stop.

Table 2 Mean changes from day 1 baseline heart rates (Δ beats min^{-1}) averaged over the relevant time periods recorded during different stages of the transport treatment on day 2. Values with superscripts are significantly different (*$P < 0.05$, **$P < 0.001$, ***$P < 0.0001$) from the corresponding day 1 values.

Treatment	Δ Heart Rate
Paddock (0815h–0830h day 1) (0805h–0830h day 2)	–4.04 ± 2.22
Yard (0831h–0850h)	–13.79 ± 3.75**
Load (0851h–0854h)	–9.03 ± 4.87
Start of Transport 1 (0855h–0900h)	5.03 ± 4.89
Transport 1 (0901h–0915h)	1.57 ± 3.92
End of Transport 1 (0916h–0920h)	2.95 ± 2.86
Stop (0921h–0931h)	–0.59 ± 3.21
Start of Transport 2 (0932h–0940h)	6.18 ± 4.55
Transport 2 (0941h–0955h)	0.64 ± 2.81
End of Transport 2 (0956h–1000h)	7.15 ± 5.37
Unload (1001–h1005h)	14.05 ± 3.36**
Unfamiliar Pen (1006h–1040h)	0.32 ± 2.02

Discussion

The results of this study indicate that the transport process affects both core (RT) and peripheral (CT and PT) temperatures in sheep. Similar increases in core body temperatures have recently been reported for sheep in response to management procedures such as transport, exercise, and presence of a dog (Parrott *et al* 1999). In the present study, a number of different components of the transport process may have contributed to the increase in core temperature, including: psychological-stress-induced hyperthermia (eg Kluger *et al* 1987); exercise-induced hyperthermia (eg Tanaka *et al* 1988) resulting from the muscular activity during yarding, loading and unloading, and the maintenance of balance during transport; and, a reduced ability to dissipate heat because of peripheral vasoconstriction (eg Cabanac & Briese 1992).

Caution must be used when interpreting the changes in core body temperature in the present study. The necessity to handle animals during the manual collection of RT may in itself have induced temperature changes, thereby confounding baseline measurements in particular. Earlier reports have shown that manipulations associated with rectal temperature measurement can modify core temperature in farm animals (Mohr & Leuschner 1989), and may elevate the animals' core temperature for up to 70 min (Poole & Stephenson 1977).

We were primarily interested in establishing whether temperature measurements obtained from more readily assessable peripheral sites could also be used to quantify the physiological response to stress. Peripheral measures of body temperature did exhibit changes with transport. However, the direction of change (hyperthermia or hypothermia) more closely reflected the change seen in ambient temperature than the general increase observed in RT.

In addition to direct ambient effects, peripheral vasoconstriction may have contributed to the decline in peripheral temperature during the initial phase of transport. Peripheral vasoconstriction may have occurred in response to stress-induced activation of the sympathetic nervous system or as a consequence of the rapid decline in ambient temperature (wind chill) during transport. A number of studies have shown that during stress, concomitant with a rise in the core body temperature, the peripheral temperature decreases. For example, the ear pinna temperature in the mouse (Cabanac & Briese 1992) and the tail skin temperature in the rat (Briese & Cabanac 1991) decrease during a stress-induced increase in core body temperature. The cutaneous response to lowering of ambient temperatures also includes peripheral vasoconstriction (Kopin *et al* 1988). In the rabbit for example, cold ambient conditions result in reduced blood flow to the ear and a significant decline in the temperature of the ear itself (Hill & Veghte 1976).

Interestingly, both CT and PT began to increase prior to the end of each of the two 25 min periods of transport, a trend also seen in the ambient temperatures recorded by sensors on the ear tags of the animals. These increases corresponded to the time during each transport period when the vehicle speed slowed to 50 km h^{-1} upon entering the city limits. It is likely, therefore, that wind chill had a significant effect on peripheral thermoregulatory responses during the transport process.

The process of transporting sheep has been reported to increase HR during loading, in the initial stages of transport and during unloading, with values generally declining over the course of transport depending upon its duration (Jacobson & Cook 1998; Knowles *et al* 1995; Parrott *et al* 1998). In the present study, many of the individual HR responses demonstrated a similar pattern, although the large variability in HR between individuals and the relatively small group size had the result that the only phases that were significantly different from the day 1 values were yarding and unloading. An interesting and unexpected finding was the lowering of HR during penning of the sheep in familiar yards. In general, acute stress is associated with a significant activation of the sympathetic division of the autonomic nervous system, which coordinates responses associated with the fight–flight response, such as tachycardia. However, increased parasympathetic activity, evidenced by bradycardia, may be seen in certain stressful situations in which a passive coping strategy involving increased vigilance is adopted (Toates 1995). Whether the observed decline in HR here is associated with a predominantly parasympathetic response or simply reflects habituation to yarding or a decline in physical activity in the yards is difficult to ascertain from the HR alone.

In conclusion, the peripheral measurement of temperature, particularly of the ear canal, may offer some potential for long-term monitoring of the thermal response to stress. However, further research is required into the potentially confounding effects of ambient temperature and wind chill factors.

Animal welfare implications

The present study confirms previous reports that transport of sheep results in stress-induced hyperthermia, manifested by an increase in core body temperature. Peripheral temperatures, however, exhibit both hyperthermic and hypothermic responses that may reflect varying levels of heat loss during the transport process. Techniques for the measurement of the thermal response to stress lend themselves to long-term automated monitoring, with the potential for widespread application in both research and industry for improving the welfare of livestock.

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References

Borsini F, Lecci A, Volterra G and Meli A 1989 A model to measure anticipatory anxiety in mice? *Psychopharmacology 98*: 207-211

Briese E and Cabanac M 1991 Stress hyperthermia: physiological arguments that it is a fever. *Physiology & Behavior 49*: 1153-1157

Broom D M 1988 The scientific assessment of animal welfare. *Applied Animal Behaviour Science 20*: 5-19

Cabanac A and Briese E 1992 Handling elevates the colonic temperature of mice. *Physiology & Behavior 51*: 95-98

Jacobson L H and Cook C J 1998 Partitioning psychological and physical sources of transport-related stress in young cattle. *The Veterinary Journal 155*: 205-208

Harris P J 1999 *The auditory evoked response as an indicator of stress in free-ranging animals.* PhD Thesis, University of Waikato, Hamilton, New Zealand

Hill R W and Veghte J H 1976 Jackrabbit ears: surface temperatures and vascular responses. *Science 194*: 436-438

Kluger M J, O'Reilly B, Shope T R and Vander A J 1987 Further evidence that stress hyperthermia is a fever. *Physiology & Behavior 39*: 763-766

Knowles T G, Brown S N, Warriss P D, Phillips A J, Dolan S K, Hunt P, Ford J E, Edwards J E and Watkins P E 1995 Effects on sheep of transport by road for up to 24 hours. *The Veterinary Record 136*: 431-438

Kopin I J, Eisenhofer G and Goldstein D 1988 Sympathoadrenal medullary system and stress. *Advances in Experimental Medicine and Biology 245*: 11-23

Marazziti D, Di Muro A and Castrogiovanni P 1992 Psychological stress and body temperature changes in humans. *Physiology & Behavior 52*: 393-395

Mohr E and Leuschner T 1989 Microcomputer assisted telemetric system for recording ultradian temperature fluctations in farm animals. *Journal of Veterinary Medicine 36*: 331-339

Morimoto A, Watanabe T, Myogin T and Murakami N 1987 Restraint stress elicits acute phase responses in rabbits. *Pflügers Archives 410*: 554-556

Nakamori T, Morimoto A, Morimoto K, Tan N and Murakami N 1993 Effects of alpha- and beta-adrenergic antagonists on rise in body temperature induced by psychological stress in rats. *American Journal of Physiology 264*: R156-R161

Parrott R F and LLoyd D M 1995 Restraint, but not frustration, induces prostaglandin-mediated hyperthermia in pigs. *Physiology & Behavior 57*: 1051-1055

Parrott R F, Hall S J G and Lloyd D M 1998 Heart rate and stress hormone responses of sheep to road transport following two different loading procedures. *Animal Welfare 7*: 257-267

Parrott R F, Lloyd D M and Brown D 1999 Transport stress and exercise hyperthermia recorded in sheep by radiotelemetry. *Animal Welfare 8*: 27-34

Poole S and Stephenson J E 1977 Core temperature: some shortcomings of rectal temperature measurements. *Physiology & Behavior 18*: 203-205

Singer R, Harker C T, Vander A J and Kluger M J 1986 Hyperthermia induced by open-field stress is blocked by salicylate. *Physiology & Behavior 36*: 1179-1182

Snow A E and Horita A 1982 Interaction of apomorphine and stressors in the production of hyperthermia in the rabbit. *Journal of Pharmacology and Experimental Therapeutics 220*: 335-339

Tanaka H, Yanase M and Nakayama T 1988 Body temperature regulation in rats during exercise of various intensities at different ambient temperatures. *Japanese Journal of Physiology 38*: 167-177

Toates F 1995 *Stress: Conceptual and Biological Aspects*. John Wiley & Sons: New York, USA