Effects of a maximum permissible journey time (31 h) on physiological responses of fleeced and shorn sheep to transport, with observations on behaviour during a short (1 h) rest-stop

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Abstract

Concern for the welfare of export lambs during long-distance road transport has prompted much research and a recommended change in procedure. The latter envisages an absolute maximum journey time of 31 h and includes a rest-stop (minimum duration 1 h) for feeding and watering. In the present experiment, the physiological and behavioural responses to this new protocol have been investigated in fleeced and shorn lambs (n = 10 per group) provided with venous catheters and heart rate monitors. The two groups were loaded on a vehicle into separate adjacent pens and driven for 14 h; then unloaded into a lairage, where their behaviour was recorded. After 1 h they were reloaded and driven for a further 15-5 h, finally arriving at a slaughterhouse where carcass condition was evaluated. Blood samples collected at 30- or 60-min intervals by experimenters travelling with the animals were analysed to determine haematocrit, plasma osmolality, plasma concentrations of glucose, creatinine phosphokinase (CPK), and the stress-responsive hormones, cortisol, prolactin, adrenaline and noradrenaline. The results showed that haematocrit increased after loading although the general trend during transport, as with osmolality, was a decline (P < 0.05). No significant changes in plasma glucose were detected but CPK increased in fleeced lambs after loading (P < 0.05). Cortisol release was stimulated by loading, especially in fleeced sheep (P < 0.001) but returned to home pen values within 6 h; heart rates changed in a similar manner. Transport did not markedly affect prolactin release although concentrations were consistently greater in fleeced sheep (P < 0.001). Noradrenaline, however, tended to be higher in shorn animals (P < 0.05). In lairage, both groups readily consumed hay, and especially concentrates, but the shorn lambs spent more time eating (P < 0.001). None of the shorn sheep, and only a few fleeced animals, drank water. There was no evidence for differences in weight loss between the two groups during the experiment and carcass quality at slaughter was within the normal expected range. The implications of these, and other related studies, for future transport policy are discussed, with particular reference to rest-stop duration and handling procedures.

Keywords: behaviour, hormones, sheep, transport, welfare.

Introduction

Long-distance road transport of export lambs, together with the handling associated with loading and lairage, is perceived as a major welfare issue. In order to assess the extent to which welfare might be adversely affected by such procedures, a number of studies have been carried out to provide information on indices of stress and injury associated with journeys of differing durations (e.g. Jarvis and Cockram, 1994 and 1995; Knowles et al., 1993, 1994a, b and c, and 1995). However, only two reports have used animals prepared with venous catheters to provide a relatively stress-free means of obtaining samples during journeys for subsequent analysis of blood chemistry and plasma hormone concentrations. One of these studies (Cockram et al., 1996) was concerned with the effects of space allowance during 12-h journeys. The other (Broom et al., 1996) compared the effects of loading on to a vehicle that remained stationary for 15 h with those of loading followed by a 15-h journey.
The new European Community Council Directive (Council of the European Communities (CEC), 1995) on long-distance road transport indicates a maximum journey time of 31 h for fleeced or shorn lambs if they are carried in a vehicle of an appropriately high quality, although this latter factor has not yet been defined. The directive indicates a period of 14 h travel followed by a rest-stop of at least 1 h for feeding and watering and then a further 14 h of transport. However, the journey time may be extended by up to 2 h to take account of the proximity of the destination, e.g. a nearby farm or slaughterhouse and there is no information yet available on the responses of sheep to this timetable of events or on the possibility that the responses of fleeced and shorn lambs may differ. Moreover, because it would normally seem to be impracticable to provide food and water on the vehicle during the rest-stop if animals are carried under commercial conditions, it would appear to be necessary to unload the sheep into lairage and then reload them again within a short interval in order to comply with the recommendations. In this connection, some responses of sheep to a 2-h rest-stop following a 15-h journey have been described (Knowles et al., 1996) although no detailed behavioural observations were made. Also, another recent study (Hall et al., 1997) has recorded food and water intake in sheep following a 14-h period in a stationary vehicle.

The objective of the present investigation was to determine whether the protocol for the new maximum permissible journey duration (i.e. 31 h) would result in poor welfare and whether shorn and fleeced sheep would be differentially affected. This was examined by recording the physiological, emotional and behavioural responses of fleeced and shorn lambs following loading, 14 h transport, lairage for 1 h, reloading and a further 15-5 h transport. The animals were provided with heart rate monitors and venous catheters, for blood sampling during transit and a variety of biochemical and endocrine indices were used to assess their welfare. Behaviour during lairage was also recorded using a video camera and analysed to provide data on the motivation to eat and drink, as well as on the pattern of non-ingestive behaviour. Finally, carcass analysis was carried out at the slaughterhouse to provide measurements of meat quality.

**Material and methods**

**Animals**

Groups of fleeced (no. = 15; five wethers, 10 ewes) and shorn (no. = 10; five wethers, five ewes) Poll Dorset lambs were housed in a communal straw-lined pen for 5 days before the start of the experiment. During this time, they were given hay and concentrates with water provided *ad libitum*.

Three days before the journey, 20 animals (10 fleeced, 10 shorn) were prepared, as previously described (Broom et al., 1996), with temporary venous catheters which were flushed daily with sterile heparinized saline. Several hours before transport, four fleeced and five shorn catheterized sheep were fitted with subcutaneous electrodes connected to non-interacting heart rate monitors (Polar Vantage NV).

**Experimental protocol**

Just before the start of the journey (12.30 to 00.00 h), blood samples (5 ml) were collected into heparinized syringes (Monovette, Sarstedt) from the catheterized animals in the home pen. The animals were then weighed and loaded via a tailgate ramp on to the vehicle (a 3.5-t standard cattle lorry with metal floor and sides). Fleeced and shorn experimental animals were arranged in separate adjacent pens in such a way as to achieve a similar space between individuals, i.e., 1.4 fleeced sheep in a 2.3 × 1.8 m pen (0.3 m² per animal) and 10 shorn + 1 fleeced sheep in a 2.3 × 1.2 m pen (0.25 m² per animal). This was necessary because the EC directive (CEC, 1995) specifies different loading densities for fleeced (0.3 to 0.4 m²) and shorn (0.2 to 0.3 m²) lambs weighing between 26 and 55 kg. The journey commenced immediately after loading with a second blood sample collected at this time (00.30 h) and the experimenters then remaining in the body of the vehicle with the animals. Blood samples were taken at 30-min intervals during the 3-h period following loading and at hourly intervals subsequently. Samples were stored on ice and unloaded every 4 h when brief stops were made to change drivers. During the subsequent 14 h period of transport animals travelled a distance of 574 miles (918 km), mainly on major roads.

Both groups of sheep were unloaded at 14.30 h, weighed and transferred to separate straw-bedded pens provided with measured amounts of concentrates, hay and water. The behaviour of each group was recorded using a video camera and the quantities of food and water consumed were subsequently determined. The animals were reloaded 60 min later and transported for a further 15-5 h (524 miles; 838 km), the last two of which involved travelling on minor roads to the slaughterhouse. Blood samples were again collected at 30-min intervals after loading and hourly thereafter. On arrival at their destination the sheep were weighed and, following slaughter, carcass analyses were carried out by a qualified (Meat and Livestock Commission (MLC)) inspector.

**Biochemical, physiological and behavioural indices**

A variety of techniques was used to investigate how the sheep responded to the journey. Indices of stress
included cardiovascular responses (heart rate) and changes in plasma concentrations of stress-responsive hormones (cortisol, prolactin, catecholamines). Muscle damage was assessed by estimating plasma concentrations of creatine phosphokinase (CPK) and carcass analysis was carried out after slaughter. Measurements were also made of other parameters known to be affected by stress and/or dehydration i.e. plasma glucose concentrations, whole blood haematocrit and plasma osmolality. In addition, behavioural observation and quantification of food and water consumption were used to assess the motivation of the animals to eat and drink during the rest-stop. A record was also made of meteorological conditions in the vehicle during the course of the journey. The details of the various measurement techniques are described below.

A haematocrit centrifuge and reader (Hawksley Ltd) was used to determine the packed cell volume (% PCV) of each blood sample. After this, the samples were centrifuged and the plasma divided into aliquots for further analysis. Plasma for samples collected at 0, 12, 24 and 31 h was stored at 4°C and estimates of osmolality were made subsequently using an automatic micro-osmometer (Roehling, Camlab Ltd); all other plasma samples were stored at -30°C. Plasma concentrations of CPK were assessed using an automatic analyser (Model CXSCE, Beckman Instruments Ltd) and plasma glucose concentrations were measured using a reader (Hypoguard Ltd) which, although primarily designed for analysis of urine samples, was found to work reliably with plasma. Previously validated radioimmunoassay procedures were used to determine plasma concentrations of cortisol and prolactin (Parrott and Goode, 1992) and established high-performance liquid chromatography methodology was employed to measure plasma concentrations of adrenaline and noradrenaline (Parrott et al., 1994). Heart rate data were downloaded via the Polar Vantage interface on to a computer and expressed as beats per min, averaged over each 20-min bin. Videotape recordings of behaviour in the lairage were analysed to determine the number of sheep eating hay or concentrates, or walking or lying, in each 5 min of the rest period. The amount of time spent in each activity was quantified and the number of approaches to water and episodes of drinking were noted. The carcass analysis included, body weight, killing-out proportion (i.e. the amount of meat), muscle reflectance (EEL units) and muscle pH recorded 45 min and 24 h after slaughter. During both journeys, sensors reporting to a multi-channel data logger (‘Squirrel’; Grant Instruments) provided information on ambient temperature and relative humidity in the space occupied by the two adjacent pens.

**Statistical analysis**

In order to assess the animals’ responses at different stages of the journey, results were compared at the four time periods tabulated below:

<table>
<thead>
<tr>
<th>Period</th>
<th>Description</th>
<th>Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First 3 h of travel</td>
<td>00.30-03.30</td>
</tr>
<tr>
<td>2</td>
<td>Remaining 11 h of first part of journey</td>
<td>03.30-14.30</td>
</tr>
<tr>
<td>3</td>
<td>First 3 h of second part of journey</td>
<td>15.30-18.30</td>
</tr>
<tr>
<td>4</td>
<td>Remaining 10.5 h of second part of journey</td>
<td>18.30 (day 1)- 07.00 (day 2)</td>
</tr>
</tbody>
</table>

Analysis of variance was used to test whether a change from home pen values occurred in each period; these comparisons were carried out independently for fleeced and shorn sheep (within-group analysis). In addition, the net change (difference from home pen value) in each period was compared between fleeced and shorn lambs (between-groups analysis). The same statistical procedures were used for all the physiological and biochemical data sets. However, in the case of osmolality, single data points corresponding to different time periods were analysed; these times were 0 h (home pen), in transit (12 and 24 h) and at the end of the journey (31 h). The behavioural and carcass analysis results were compared using t tests. All probability values given are two-tailed.

**Results**

**Blood measurements**

**Haematocrit.** The effects of loading and transport on %PCV are shown in Figure 1. The data indicate a rise in response to loading in both groups of sheep, followed by a fall to readings below those recorded in the home pen. Subsequently, values during the remainder of the first part of the journey (period 2) were relatively constant. However, reloading after lairage appeared to induce another increase in fleeced sheep and both groups exhibited further decrease in %PCV during the second stage of the journey (period 3 and part of period 4). The ‘within-group’ analysis indicated that haematocrit decreased in both fleeced and shorn animals during periods 2 to 4 (fleeced, $P<0.01$, $P<0.01$, $P<0.001$, respectively; shorn, $P<0.05$, $P<0.01$, $P<0.01$, respectively). Moreover, the only difference between the groups was a greater reduction in %PCV in shorn lambs in period 3 ($P<0.01$).
Creatine phosphokinase. Changes in CPK concentrations are illustrated in Figure 2. Although greater variability was apparent in the results obtained from fleeced sheep in periods 1 and 2, these animals, nevertheless, exhibited an increase ($P < 0.05$) in CPK in response to loading and the start of travel (period 1). The ‘between-groups’ analysis also indicated that the fleeced, but not the shorn, lambs showed a rise ($P < 0.01$) in CPK concentrations at this time.

Plasma glucose. Although the results (Figure 3) suggest that concentrations tended to increase in response to loading in shorn sheep, neither analysis detected any significant treatment effects or group differences.

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Osmolality. Estimates of plasma osmolality obtained from samples taken in the home pen during both periods of travel and at the end of the experiment are shown in Figure 4. Osmolality was lower during travel towards the end of period 2 (at 12:00 h) than in the home pen in both fleeced (P < 0.01) and shorn (P < 0.05) lambs. Values were restored to home pen levels during the second part of the journey following lairage (00:00 h, period 3) and were reduced again, although not significantly, at the end of the journey (07:00 h day 2, period 4). However, the ‘between-groups’ analysis indicated that at no time were the results obtained from fleeced and shorn sheep significantly different.

Cortisol. Patterns of hormone release (Figure 5) were similar in both groups of sheep. Concentrations increased in response to loading and the start of the first part of the journey and then steadily declined to reach a nadir at 07:00 h (period 2), subsequently followed by a small increase. Reloading after lairage (period 3) appeared only to have a small stimulatory effect on cortisol release. Concentrations during the remainder of the journey (period 4) remained low until the final 2 h of travel when a marked increase was apparent. Home pen values were rather variable in shorn sheep and none of the results obtained during periods 1 to 4 showed significant changes when compared using the ‘within-group’ analysis. By contrast, fleeced animals were found to have greater (P < 0.001) cortisol concentrations in period 1. The ‘between-groups’ analysis also indicated a greater decrease in plasma cortisol in shorn lambs during period 2 (P < 0.05).

Figure 5 Plasma concentrations of cortisol (nmol/l; mean with s.e.) in fleeced (■) and shorn (□) lambs at different stages of the 31-h experimental period, as described in the legend for Figure 1. The increase in hormone concentrations during the first 5 h of transport was significant for fleeced animals (see text for details).

Figure 6 Plasma concentrations of prolactin (nmol/l; mean with s.e.) in fleeced (■) and shorn (□) lambs at different stages of the 31-h experimental period, as described in the legend for Figure 1. There were no significant effects of transport but hormone concentrations were higher in fleeced animals (see text for details).

Prolactin. There were no significant effects of transport on prolactin concentrations (Figure 6) in either group although there was a tendency for concentrations to rise during the second stage of the journey (period 3) in shorn sheep. The most obvious feature of these data, however, is the higher hormone concentrations found in fleeced lambs throughout the course of the experiment. An additional analysis indicated that this difference was statistically significant (P < 0.001).

Noradrenaline. No significant treatment effects or group differences in plasma concentrations (Figure 7a) were found. However, hormone concentrations tended to be consistently higher in shorn sheep and to show an increase during the second stage of the journey (periods 3 and 4). An additional analysis indicated that values were greater in shorn lambs in periods 2 (P < 0.01), 3 (P < 0.05) and 4 (P < 0.05).

Adrenaline. Hormone release appeared to be stimulated when transport recommenced after lairage (period 3), especially in shorn animals (Figure 7b). This was reflected by higher concentrations in this group, as revealed by the ‘within-group’ analysis (P < 0.05). No other significant differences were found.

Animal measurements

Heart rate. Measurements were obtained from most of the instrumented sheep during the first part of the journeys whereas, due to displacement of electrodes, the results are incomplete for the period after lairage. Inspection of the data collected during the first 14 h
Figure 7 Plasma concentrations (nmol/l; mean with s.e.) of (a) noradrenaline and (b) adrenaline in fleece (■) and shorn (□) lambs at different stages of the 31-h experimental period, as described in the legend for Figure 1. At certain stages of the experiment, concentrations of both catecholamines were significantly greater in shorn animals (see text for details).

(Figure 8) indicates that heart rate rose in both groups after loading, stayed high during the first 9 h of travel and then began to decline. Neither of the analyses detected any significant difference although the ‘within-group’ comparison indicated that the increase over home pen values in fleece sheep approached significance (P < 0.06) in fleece lambs in period 1.

Activity during the rest period. The temporal pattern of behaviour exhibited during the rest period by the two groups of sheep is shown in Figure 9. The upper graph (a) indicates that fleece lambs consumed the concentrates over the first 35 min but also began eating hay after 10 min. Several sheep walked about and some lay down at the end of the rest period. In the case of the shorn lambs (b), all the concentrates were consumed in the first 10 min and then the animals changed to hay which most ate for the remainder of the time. A few sheep moved around but none was observed to rest. Time budgets derived from these data are illustrated in Figure 10. The upper graph (a) shows that although sheep in both groups ate all of the concentrates (500 g), the shorn lambs consumed them significantly (P < 0.001) faster; they also spent more time eating hay (P < 0.01) and none was seen to lie down. The total amount of hay eaten by fleece and shorn sheep was 2.75 and 2.85 kg, respectively. Very few of the animals showed any interest in drinking but estimates of actual water consumption were not possible due to spillage. However, the video record showed that
Physiological responses of sheep to transport

![Graphs showing number of fleeced and shorn sheep engaged in different activities over time.](image)

**Figure 9** Number (No.) of (a) fleeced and (b) shorn sheep engaged in eating concentrates (●), eating hay (○), walking (●), or lying (○), in each 5-min period of the hour spent in lairage between the two parts of the journey.

Although some sheep in both groups approached the water containers (Figure 10b), only the fleeced animals drank (P < 0.05).

**Body weight and carcass analysis.** Sheep in both groups lost about 3-6 kg during both the first and the second parts of the journey. Differences in body weight did not differ between fleeced and shorn animals at any stage of the journey (Figure 11). However, the amount of meat on the carcass (killing-out proportion) was greater (P < 0.05) in fleeced lambs. No significant differences between the groups in measures of carcass quality (muscle reflectance; muscle pH at 45 min and 24 h) were detected.

**Environmental data**

Inversely related changes in ambient temperature and relative humidity recorded in the space occupied by the animal pens are shown in Figure 12.

**Figure 10** Quantification of behaviour displayed while the sheep were in lairage. (a) The upper graph shows the total amount of time (duration in min; mean with s.e.) that fleeced (shaded columns) or shorn (open columns) lambs spent eating concentrates or hay, or walking, or lying. Differences between the groups were significant for consumption of concentrates and hay (both P < 0.001) and also for walking (P < 0.05). (b) The lower graph shows the number (mean with s.e.) of approaches to water and drinking episodes, per 5-min periods, recorded in fleeced (shaded columns) or shorn (open columns) lambs while in lairage; drinking occurred more frequently (P < 0.05) in fleeced animals.

**Discussion**

This is the first study to examine some of the behavioural and physiological responses of sheep transported under conditions complying with the new European Union road transport directive. In practice, this experiment represents an extension of an earlier investigation (Broom et al., 1996) in which lambs were transported for 15 h, the difference being that the present study involved two periods of travel (14 and 15.5 h) separated by a 1-h rest-stop. The directive specifies different space allowances for fleeced and shorn lambs and the use of both types of animal in the present study provides information on the relationship between shearing and transport stress. In addition, the sheep in this experiment had
no prior experience of transport procedures, in contrast to previous studies (Broom et al., 1996; Cockram et al., 1996) where there was re-use of animals. Nevertheless, the findings, with respect to the effects of loading and transport, are not greatly different from those reported in the previous investigation by this group (Broom et al., 1996) although, new information was obtained on the behaviour during lairage. It is also of note that there were few occasions during transport where the responses of fleeced and shorn sheep were significantly different with respect to the non-behavioural variables measured whereas the behaviour recorded in the lairage did differ significantly between the two groups.

Stress can cause increases in PCV in sheep due to the release of erythrocytes from the spleen. A response of this nature was noted following unloading in a
former transport study (Cockram et al., 1996) but not in the experiment carried out by Broom et al. (1996). However, in the present investigation, haematocrit increased sharply in fleeced lambs on both occasions that they were loaded and in shorn animals only after the first loading. Also, in addition to this transient increase, both groups of lambs displayed significant decrease in haematocrit, compared with home-pen readings, as a consequence of transport. This confirms results from the 15-h study (Broom et al., 1996) where it was speculated that cortisol release in response to prolonged transport may cause a redistribution of body fluids and a resultant haemodilution.

In parallel with the fall in haematocrit, sheep also show decreases in osmolality during long journeys (Broom et al., 1996). This was observed in both fleeced and shorn lambs during the first stage of the present journey. However, osmolality was restored to home-pen concentrations half-way through the second part of the journey, probably as a consequence of food ingestion during the rest-stop. At the end of the journey, osmolality was again reduced, although not significantly so. These results support previous findings showing that feeding unaccompanied by drinking, as in this study, increases plasma osmolality in sheep (Parrott et al., 1996). However, the transport-induced fall in osmolality appears to be a stress effect because penned, but otherwise unstressed, sheep deprived of both food and water for periods much longer than 15 h do not exhibit this response (Parrott et al., 1996). Thus, sheep do not seem to become dehydrated during 31-h journeys but eating, without drinking, during the rest-stop can increase the osmotic concentration of the plasma. However, whether this leads to negative water balance may depend upon ambient temperature and how well the sheep adapt to the journey.

Measurement of plasma CPK provides an index of tissue damage. Neither the present, nor the previous 15-h study (Broom et al., 1996) detected any injurious effects of transport. However, loading increased CPK concentrations in fleeced, but not in shorn, lambs and unloading had a similar effect in fleeced animals in another investigation (Cockram et al., 1996). These changes might have been brought about by some physical disturbance to the fleece, although attempts were made to avoid wool-pulling during loading.

Heart rate data were only representative for the first stage of the journey. Loading increased cardiac activity and this was sustained for the first few hours of travel before decreasing; these observations resemble those reported for an individual animal in the previous study by this group (Broom et al., 1996). In addition, changes in heart rate showed a similar pattern in both fleeced and shorn lambs.

Four stress-responsive hormones (cortisol, prolactin, adrenaline and noradrenaline) were measured in these experiments and, of these, cortisol provided the most useful information with regard to welfare during transport. In the previous study (Broom et al., 1996), cortisol concentrations increased after loading, declined gradually over the next few hours and then remained relatively constant, but at above baseline values, during the rest of the journey. A similar pattern was observed during the first period of travel in the present experiment, although significant effects were detected only in fleeced lambs. Moreover, although peak cortisol concentrations in this study happen to coincide with the time of maximal secretion (01.00 h; Fulkerson and Tang, 1979) the increase between 00.00 and 01.00 h in non-stressed sheep is proportionately about 0-20 whereas loading and transport induced increases that were proportionately much greater (fleeced 2-10; shorn 1-00). Also, interestingly, the cortisol response to the second loading was markedly reduced, suggesting that the animals may react more to the novelty of the situation than to the effects of handling. In this connection, it has been found that sheep transferred to an environmental chamber show an initial increase in cortisol concentrations (Parrott et al., 1996). Moreover, loading on to the same vehicle did stimulate cortisol release on a second occasion when both events were separated by a longer (6-day) interval (Broom et al., 1996). However, in another report (Cockram et al., 1996) loading followed by transport, but not loading on its own, elicited a cortisol response. Finally, all transport studies carried out thus far indicate that cortisol concentrations decrease during transit, providing evidence that, in this respect at least, sheep readily adapt to motion stimuli. However, it was apparent in the present investigation that the change to minor roads during the final 2-h period of travel to the slaughterhouse tended to induce cortisol release in both groups of lambs. This suggests that although sheep may adapt to transport stimuli when travelling on major roads, journeys on secondary roads with poor surfaces may cause distress.

Loading and transport effects on prolactin release, similar to the changes described for plasma cortisol (above), have been noted in previous reports (Broom et al., 1996; Cockram et al., 1996). However, in the present study, effects of transport on prolactin secretion were less obvious. The first loading seemed to induce a brief surge in prolactin in fleeced lambs and plasma concentrations also appeared to rise during the early part of the second stage of the
journey in shorn lambs, although no significant treatment effects or group differences were detected. Nevertheless, the main finding with respect to prolactin was a consistent difference between the two groups, i.e. higher concentrations in fleeced animals, that was independent of transport. The most plausible explanation for this finding is that it relates to differences in thermoregulatory activity. A previous study indicated that prolactin concentrations were positively associated with ambient temperature in sheep (Parrott et al., 1996) and other evidence (Salah et al., 1995) suggests that prolactin may lower heat production in animals exposed to high ambient temperatures. Thus, due to the insulation provided by the wool, fleeced sheep may have an altered metabolism linked to a different pattern of hormone secretion.

This is the first study to investigate the effects of transport on catecholamine release. Previous work has shown that both acute (Parrott et al., 1994) and (Ley et al., 1992) distressing chronic situations can affect the plasma concentrations of these hormones in sheep. Also, sheep placed in a transport simulator which produces exaggerated yaw and pitch show increased release of adrenaline (Parrott et al., 1994). Long-distance travel in the present study, however, appeared to stimulate the release of both hormones but significant increases over home-pen values were only found for adrenaline in shorn lambs during the period following lairage. In addition, concentrations of noradrenaline were generally higher in shorn animals. It is possible that increased sympathetic activity in this group may reflect persistent metabolic effects of shearing because shorn sheep are unable fully to compensate for the deficit in energy that this induces (Black and Chestnutt, 1992); these findings may be related to the lower prolactin concentrations referred to earlier.

Anecdotal reports by other workers suggest that sheep are primarily interested in feeding following long-distance road journeys (Knowles et al., 1993, 1995 and 1996) and a detailed study (Hall et al., 1997) indicates that food intake is the first priority in sheep offered food and water after 14 h in a vehicle. The results of the present study, in which behaviour in the lairage was recorded in some detail, confirm these observations. In this connection, it may be relevant that tooth-grinding was noted in sheep held for 15 h on a stationary vehicle (Broom et al., 1996) and, although not previously documented during transport, this behaviour may signify hunger. Clearly, the present results show that concentrates were preferred to hay by both groups of animals and that the shorn lambs, probably because of their greater energy requirements (Black and Chestnutt, 1992), consumed the pellets more rapidly and spent more time eating. The fleeced animals, however, appeared to be more readily satiated and some took the opportunity to rest. Both groups showed little interest in water and only a few fleeced animals drank. Other reports also indicate that, depending upon the type of food offered, at least 2 h is needed for post-prandial drinking to occur in such situations (Knowles et al., 1996) and that this may continue for a further 4 h (Hall et al., 1997). Therefore, with only a brief rest-stop, there is a possibility of negative water balance developing subsequently.

The measurements of temperature and humidity indicated that conditions in the vehicle during transport were within the normal meteorological range for the time of year. Also, examination of carcasses at the end of the experiment did not provide any evidence for a marked reduction in meat quality as both the EEL units and pH measurements were within normal accepted limits (M. Owen, MLC, personal communication). Less meat was obtained from the shorn than fleeced lambs, possibly due to differences in metabolism but the overall amount of weight lost at each stage of the journey was the same for both groups.

In conclusion, and in agreement with previous observations, these data suggest that although sheep find loading distressing, this may be related more to unfamiliarity with the procedure rather than to the effects of poor handling. However, all the evidence suggests that the animals seem to show adaptive responses to transport within a few hours, providing that road and vehicle conditions are good. Journeys lasting between 14 and 16 h seem to be well tolerated and there is no evidence to suggest that the experience inhibits feeding, although data on the extent of fatigue and food utilization would provide a fuller picture. The animals do not become dehydrated during transit and are not motivated to drink during the rest-stop until sometime after they have finished eating. Fleeced lambs may suffer from heat stress and tissue damage due to wool pulling whereas shorn animals, which already have an energy deficit, may become chilled and exhibit a higher motivation to eat. Given that the provision of food and water in the vehicle is unlikely to provide for the needs of all animals, unloading followed by a period in lairage of sufficient length for post-prandial drinking (i.e. up to 6 h) to occur is necessary. Thus, the 31-h timetable, as recommended, seems to have certain disadvantages from the welfare viewpoint. In order to allow for the sheep to be given time to recover from the effects of a transport and also for a change of drivers, a protocol consisting of 16 h travel and 8 h in lairage might be more suitable. It may be that this procedure could be repeated on a daily basis so that long distances could be covered without
inducing poor welfare. However, further research is needed to address this issue.

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