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AN INVESTIGATION OF THE RELATIONSHIPS BETWEEN BODY TEMPERATURE AND IMPLANTATION AND LAMBING RATES IN THE NEW ZEALAND ROMNEY EWE

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SUMMARY

Rectal temperatures of Romney ewes, of four different ages, were measured at four observation periods during the mating season, using an experimental design to allow for ambient temperature and other effects. The number of eggs shed (represented by fresh corpora lutea) at the first two oestrous periods were determined for half the sheep by laparotomy. The numbers of lambs born to each ewe were recorded.

Real effects ($P < 0.05$) were found in that 2- and 3-year-old ewes had higher body temperatures (103.2, 103.0° F), than older ewes (102.8° F). In addition, the body temperature fell during the oestrous cycle with a rise (+ 0.35° F) about the time of oestrus and ovulation.

The body temperature at about the time of implantation of the blastocyst was higher for ewes having no lamb, and for those having singles, than for those having twins (103.4, 103.2, 103.1° F, respectively). Results from laparotomy showed that ewes failing to implant two eggs had higher body temperatures than those failing to implant one egg, or of ewes successfully implanting all the eggs shed (103.4, 103.2, 103.1° F, respectively). It appears that a body temperature greater than 103.2° F may affect implantation and the consequent number of lambs born.

THIS paper reports on a study in which rapid techniques for the measurement of rectal temperature (Cockrem and Sutcliffe, 1968) and laparotomy to observe ovaries (Lamond and Urquhart, 1961) were used in sheep under field conditions with the objective of examining whether body temperature differences existed between ewes with differing implantation and lambing rates.

Cockrem (1962) has suggested the measurement of certain physiological characteristics in sheep could be a useful aid in the investigation of problems of breeding for higher fertility. Measurements of the body temperatures in woolly-faced and open-faced Romney ewes (Cockrem, 1967) have shown that differences (possibly genetic in origin) existed in the ability of sheep to control their body

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temperature. Raised body temperatures in ewes subjected to elevated ambient temperature is associated with a depression in fertility owing to impaired embryonic development (Alliston and Ulberg, 1961; Ryle, 1961). Recently, Cumming (1965) has shown that, after egg-transfer, fewer embryos developed in woolly-faced Romney ewes than in open-faced sheep. Thus it seemed possible that fertility differences between woolly- and open-faced ewes may be associated with differences in body temperature early in pregnancy.

MATERIALS AND METHODS

Animals and Observations Made

Romney ewes of four age-groups (rising 2, 3, 4 and 6 years) and known history were available from a flock maintained at Massey University. The sheep were allocated into two groups; those in the first group were laparotomized 4 to 7 days after both the first and second oestrous periods of the breeding season, while the remainder were not operated on. At laparotomy, the numbers of fresh corpora lutea were recorded as evidence of numbers of ova released into the genital tract during the previous oestrus. The ewes were also randomized to six ram mating groups, each ram being allotted both laparotomized and non-operated ewes. Fertile matings were allowed at second oestrus and at later times. Rectal temperatures were recorded as described by Cockrem and Sutcliffe (1968) for each sheep during four periods at 10-day intervals, starting March 19, 1968. Temperatures were recorded in the morning and again in the afternoon, the time of measurement being random for any sheep except those subjected to laparotomy on that day. Because of the numbers of sheep involved, measurements each period were made over two days; sheep were randomized to Day 1 or Day 2, for each period. The sheep were weighed before and during the experimental period and also graded for face cover by the method of Cockrem and Rae (1966). Lambing data were recorded daily.

Analysis of Data

Because of the unequal sub-class numbers, estimates of the various effects were made by least squares followed by the appropriate analyses of variance. Preliminary estimates of sub-class means were made to determine where interaction was likely to be of importance.

Analyses were made to determine:

(a) The factors affecting body temperatures and the effectiveness of the experimental design. The choice of model depended on the results from analysis of the previous model and some preliminary estimates.

Model I: $Yijklm = \mu + L_i + A_j + T_k + P_l + (TP)_{kl} + Eijklm$

Model II: $Yijklm = \mu' + OE_i + A_j + G_k + P_l + (GP)_{kl} + Eijklm$

Where μ, μ' are general means,

L	$i = 1$	Laparotomized, 2 Not laparotomized
A	$j = 1, 4$	Age of ewe
T	$k = 1$,	a.m. 2, p.m.
P	$l = 1, 4$	Period of measurement.
(TP)		Interaction.
OE	$i = 1, 8$	Stage of oestrous cycle by 2-day intervals. 9 = pregnant, 10 = no oestrous activity.
G	$k = 1, 3$	Face cover grade.

For Model I, time of measurement was tested as a covariate and the randomization between times and days was also tested.

For Model II, a.m. and p.m. temperatures were analysed separately and body weight was tested as a covariate.

(b) Temperature differences between fertility characteristics.

The variable analysed was the first temperature taken after the ewe became pregnant, or the final temperature recorded in Period 4. In considering data for laparotomized ewes, those not lambing within 152 days of the second laparotomy were assumed to have implanted no eggs; the lambs born were those to a subsequent mating and the final temperature will have been analysed. Apart from this, the numbers of eggs failing to implant were estimated from the numbers of lambs born and the eggs shed at second oestrus. The analyses were:

Non-Laparotomized ewes:

Model III: $Yijkl = \mu + A_i + B_j + G_k + (BG)_{jk} + Eijkl$

Laparotomized ewes:

Model IV: $Y'ijkl = \mu' + A_i + B_j + G_k + (BG)_{jk} + E'ijkl$

Model V: $Y''ijkl = \mu'' + A_i + C_j + G_k + (CG)_{jk} + E''ijkl$

Model VI $Y'''ijkl = \mu''' + A_i + D_j + G_k + (DG)_{jk} + E'''ijkl$

Where effects additional to first equations are:

B_j lambs born $j - 1 = 0,1,2$
C_j eggs failing to implant $j - 1 = 0,1,2,3$
D_j total eggs shed at first and second oestrus, $j - 1 = 0 - 5$,

Y and E follow the usual conventions. Analysis was made by a linked series of computer programs which provided a completely automated analysis from the raw data to the analyses of variance and covariance. The computational method follows that of Harvey (1960) and will be described elsewhere.

RESULTS

LAMBING PERCENTAGES AND FERTILITY DATA

Table 1 shows the average lambing percentages, the total number of eggs shed per ewe, and the number of eggs failing to implant per ewe. The averages are weighted for age effects within the face cover grades. Table 2 shows the number of ewes in each classification and the number of degrees of freedom for each analysis. It is clear that there were no consistent differences in these fertility data between the face cover groups as a minimum of 15% difference is required for a real effect based on the size of the groups. There was, however, an effect of the operation procedure on percentages of lambs born.

FACTORS AFFECTING BODY TEMPERATURE

Model I

There was no effect of the laparotomies on the measured temperatures, but age, period and the time × period inter-

TABLE 1: THE LAMBING PERCENTAGES AND FERTILITY DATA AS AVERAGES WEIGHTED FOR AGE OF EWE

	Face Grade*			
	1	*2*	*3*	*Average*
Operated ewes				
Lambing %	92.9	84.7	83.2	87.0
Eggs shed/ewe†	2.31	2.26	2.39	2.32
Eggs lost/ewe	0.53	0.67	0.55	0.60
Non-operated ewes				
Lambing %	105.0	98.7	108.9	104.2

*1 is woolly-, 2 medium-, 3 open-faced.
†Total for two oestrous periods.

TABLE 2: THE NUMBER OF EWES MEASURED AND THE DEGREES OF FREEDOM FOR EACH ANALYSIS

Age of Ewe (yr)	*Operated Ewes Face Grade*				*Non-operated Ewes Face Grade*			
	1	*2*	*3*	*Total*	*1*	*2*	*3*	*Total*
2	28	27	21	76	9	24	8	41
3	7	19	11	37	6	24	7	37
4	12	21	9	42	16	21	8	45
6	26	40	19	85	22	31	13	66
Total	73	107	60	240	53	100	36	189

Degrees of freedom for residual mean squares with interaction:

Model	I	II	III	IV	V	VI
D.F.	3556	1727	177	228	210	204

TABLE 3: THE ESTIMATED WEIGHTED MEANS (° F) FROM MODEL I WITH F VALUES FROM ANALYSIS OF VARIANCE

	Age of Ewe (yr)				
	2	*3*	*4*	*6*	*F*
Mean	103.2	103.0	102.8	102.9	83.5***
	Measurement Period				
	1	*2*	*3*	*4*	*Overall*
Time a.m.	103.0	102.9	102.8	103.3	103.0
p.m.	102.8	103.1	102.8	103.2	103.0
Overall	102.9	103.0	102.8	103.3	103.0
Ambient ° F	70	72	63	59	

F values: Time < 1; Period 101.9***; Time $\times$ Period 22.6***.
***$P < 0.001$.

action all showed significant differences ($P < 0.001$). Table 3 shows the estimated means from the model, including interaction. The results indicate that young ewes have higher temperatures than older ewes and that the conditions at the time of measurement are important. The lower temperatures for Period 3 were probably associated with a hurricane (April 10, 1968) with a drop of 25° F in ambient temperature at this time.

The time $\times$ period interaction arose from higher temperatures in the morning of the first period which could have been associated with the sheep not being accustomed to insertion of the rectal probe (see Cockrem and Sutcliffe, 1968). The regression on time of measurement was significant ($P < 0.05$), but the effect was small (0.09° F over the day) and, as the sheep were randomized with respect to the time, this effect was not considered important.

Model II

Because of the time × period interaction in Model I, a.m. and p.m. temperatures were analysed separately.

Age and period effects were similar to those from Model I. There were no clear-cut differences associated with face cover. Allowing for relationships between a.m. and p.m. temperatures, the standard deviation for an individual sheep was 0.439° F. This would include the error variation and variation between sheep not explained by factors in this model.

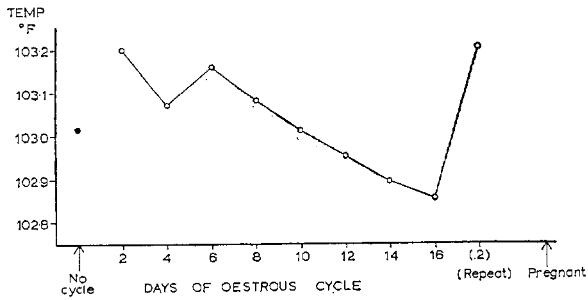

FIG. 1: *Mean a.m./p.m. body temperatures. Data adjusted by Model II.*

The main effect that was of interest was stage of oestrous cycle ($P < 0.001$) for differences) and the mean a.m./p.m. temperature for this classification is shown in Fig. 1. There was little difference in the estimate for the two times (Day 1, Day 2) for any particular stage of oestrous cycle. There is a drop of temperature throughout the cycle with a rise of 0.35° F at about the time of oestrus and ovulation.

Model III

There were no interaction effects ($F < 1$) in this analysis and the results presented are from the model without interaction. Table 4 shows the effects for numbers of lambs born for body temperatures in early pregnancy ($P < 0.01$) body weight ($P < 0.05$) in March, and weight gain ($P < 0.01$) during the mating season. All these effects were probably real. Dry ewes had a body temperature of 0.4° F above ewes having singles or twins. The weight and weight gain results relative to numbers of lambs born were inconsistent relative to lambing status.

TABLE 4: ESTIMATED MEANS FROM MODEL III (NON-OPERATED EWES) AND F VALUES

	No. of Lambs Born 0	1	2	F†
Temperature (° F)	103.5	103.1	103.0	6.96**
Body weight (kg)	56.1	54.2	57.5	3.82*
Weight gain (kg)	— 10.2	— 1.6	— 3.9	5.84**

†No interaction model.
*$P < 0.05$; **$P < 0.01$.

Model IV

Results were similar to those for Model III and are also presented from the model without interaction ($F < 1$). The significant results (temperature, $P < 0.05$; weight gain, $P < 0.001$), classified by the number of lambs born, are shown in Table 5. They confirm the previous model, except that weight losses were greater over the period for those ewes failing to lamb.

Model V

Interaction between "eggs failing to implant" and "face cover", might have been a real effect ($P < 0.08$), so the model with interaction was used. Apart from age effects, there were no differences associated with weight. There were, however, differences of body temperature associated with the number of eggs failing to implant ($P < 0.05$). There were no direct face cover effects. Because of the possible interaction, the full table of face cover and "eggs lost" estimates is presented in Table 6.

A higher body temperature is associated with one or two eggs failing to implant, while the interaction appears to result from the high temperature of woolly-faced sheep losing two eggs. The standard error of the sub-class means is approximately 0.16° F (based on average sub-class number without allowance for disproportion). For weight gain, there were differences such that those ewes implanting all eggs showed less weight loss.

Model VI

There were no temperature differences associated with the total number of eggs shed over the two oestrous periods. There were, however, significant weight and weight gain differences (no interaction model). The estimates are shown in Table 7. There were few animals with

TABLE 5: ESTIMATED MEANS FROM MODEL IV (LAPAROTOMIZED EWES) AND F VALUES

	No. of Lambs Born 0	1	2	*F*†
Temperature (° F)	103.4	103.2	103.1	4.55*
Weight gain (kg)	— 5.3	— 2.0	— 1.0	17.6***

†No interaction model.
*$P < 0.05$; ***$P < 0.001$.

TABLE 6: ESTIMATED MEANS FROM MODEL V AND F VALUES

	Body Temperature (° F)			
Face Grade	*No. of Eggs Lost* 0	1	2	*Overall*
1	103.0	103.2	104.0	103.4
2	103.1	103.1	103.3	103.2
3	102.9	103.4	103.1	103.2
Overall	103.1	103.2	103.4	

F values: Eggs lost, 3.79*; Face grade, 1.40; interaction, 2.06.
F for $P < 0.05$, for interaction (D.F. 4,210) = 2.40.

	No. of Eggs Lost 0	1	2	*F*
Weight gain (kg)	— 1.4	— 4.2	— 4.1	15.5***

*$P < 0.05$; ***$P < 0.001$.

TABLE 7: ESTIMATED MEANS FROM MODEL VI AND F VALUES

	No. of Eggs Shed, 1st and 2nd Oestrus Combined 0	1	2	3	4	5	*F*
Body weight (kg)	57.7	54.7	54.3	56.0	57.7	61.8	2.42*
Weight gain (kg)	— 7.5	— 6.3	— 2.5	— 2.1	— 1.6	— 4.0	3.98**
n	4	16	124	50	29	2	

*$P < 0.05$; **$P < 0.01$.

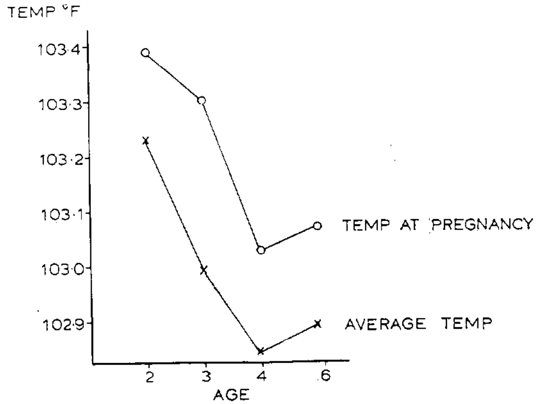

FIG. 2: *Estimated body temperatures and temperatures in early pregnancy relative to age.*

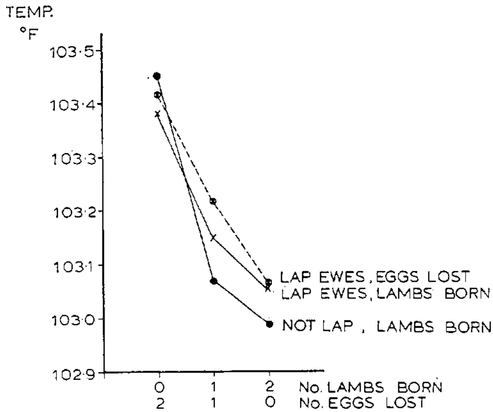

FIG. 3: *Estimated body temperatures relative to the number of lambs born or eggs lost.*

0 or 5 eggs shed and these estimates are likely to be inaccurate. For the remainder of the sheep, it appears that a slightly higher body weight and, in particular, a smaller weight loss were associated with a greater number of eggs shed.

The main results from these analyses are summarized in Fig. 2 which shows the effect of age on the relevant temperatures and in Fig. 3 which shows temperatures related to lambing data. The estimated body temperatures for lambing groups for operated and non-operated groups show reasonable agreement. Furthermore, the tempera-

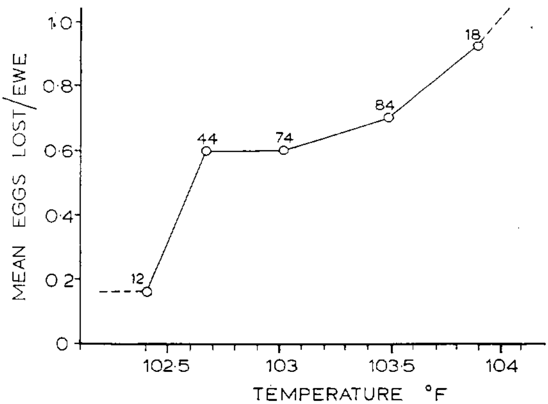

FIG. 4: *Mean eggs lost per ewe plotted against mean temperatures of number of ewes shown. Data not adjusted by least squares analyses.*

tures classified by the number of eggs failing to implant show close agreement with those from the subsequent lambing.

Figure 4 shows the mean number of eggs lost per ewe plotted against body temperature. This illustrates the result from the analyses and suggests that temperatures above 103.2° F may be critical for events associated with implantation and early embryonic development.

DISCUSSION

The work described in this paper had three main objectives.

(1) The assessment of a physiological measurement on a large scale in the field.

(2) To test whether there were body temperature differences associated with face cover differences.

(3) To test for possible body temperature differences associated with implantation.

The first objective was successful in that the experimental plan used enabled the detection of differences in temperature by age and the period of measurement. In particular, temperature changes over the oestrous cycle were capable of detection and estimation. Thus, given a plan which will allow for removal of extraneous variation in a statistical analysis, there appears to be little reason why methods of this type should not be applied further. However, a detailed examination of day-to-day fluctuations in a few sheep at the same time, if possible by telemetry, is desirable to provide an adequate interpretation of the results.

The second objective gave no clear-cut result. This could mean that differences between face cover grades in body temperature do not occur under the conditions encountered. However, differences in lambing percentage between grades were not found and body weight differences were small. This suggests that the sample was unusual in that such differences have nearly always been found previously (see Cockrem and Rae, 1966). There are two possible reasons. First, that the mixed age of the ewes, with different previous shearing dates, had affected the gradings for face cover. Secondly, and more likely, that there was insufficient variation in face cover for major detectable differences to be present.

The third objective was to test for possible body temperature differences associated with ovulation and implantation rates and the consequent number of lambs born. In the present experiment, the evidence was that ovulation rate was not related to temperature, but that implantation rate and the number of lambs born showed clear-cut differences. These were such that those ewes implanting fewer eggs and having fewer or no lambs were those with higher body temperatures in early pregnancy. Temperature differences associated with the number of lambs born for laparotomized and non-laparotomized sheep gave good agreement both for the estimates and for the statistical significance of the effects.

The use of the number of eggs failing to implant was valid for the temperature comparisons as temperature was random with respect to the number of eggs shed. However, the interpretation of weight gain differences which occurred in data for both numbers of eggs shed and eggs failing to implant could be complicated by a ewe shedding two eggs having a higher probability of an implantation failure than a ewe shedding one egg at an oestrous period.

The estimates obtained of body temperature were adjusted for age differences. However, although young ewes had higher absolute body temperatures, they did not fail to implant more eggs. This suggests that absolute level of any temperature effect may vary with age.

Considering all the evidence, it appears that body temperatures above 103.2° F could lead to some implantation failure, while ewes with temperatures above 104.2° F are unlikely to have a lamb. These are average temperatures and cover 10-day intervals. More detailed studies are required to determine whether short critical periods exist and what the relationships of body temperatures over such possible periods might be with the average temperatures measured here.

The differences in body weight gain over the mating period associated with eggs shed and implanted, point to the importance of management over this period. While some absolute body weight differences were found associated with eggs shed, the variance associated with these was low ($F = 2.42$) and they were not very consistent.

While it is clear that little information exists as to the detailed mechanisms involved in the effects demonstrated, the occurrence of these associations of temperature and implantation has a number of implications. Ambient temperatures in the Manawatu district, where these observations were made, are not as high as in some other New Zealand districts where low lambing percentages are a problem. It may well be that selection for appropriate strains of sheep which can control their body temperature is required for these districts such as in North Auckland, Gisborne, and Hawke's Bay. Selection for Merino strains which can maintain a relatively low body temperature is already taking place in North Queensland (A. T. Bell, pers. comm.). As this approach has been indicated by New Zealand work (Cockrem, 1967), it would seem appropriate that an environmental study might be applied in certain regions of this country.

A further important use could be in the preliminary screening of new breeds being imported for crossbreeding purposes. Body temperature has the advantage that it can be measured in both ram and ewe. It is quite possible that breeds showing high fecundity in such climates as Germany and Finland would be unsuitable for the New Zealand environment. Consideration of physiological characteristics underlying lambing percentages would appear to be a sound approach in addition to the published results for breeds in their own environment.

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