Interpretative Summary: Udder conformation, Milk Somatic Cell Count and Lamb Weight in Suckler Ewes. Huntley.

Poor udder conformation and teat position were associated with high somatic cell count (SCC) in ewes suckling lambs (suckler ewes). Both poor udder conformation and high SCC were associated with rearing lighter lambs to weaning. To date there has been no attempt to select suckling ewes with good udder conformation and teat position: should these phenotypes be as heritable as reported in dairy cows and dairy sheep then rapid improvement in udder conformation and teat position could be achieved. This in turn would improve mammary health and the growth of suckling lambs.

A Cohort Study of the Associations between Udder Conformation, Milk Somatic Cell Count, and Lamb Weight in Suckler Ewes

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ABSTRACT

A cohort study of 67 suckler ewes from one flock was carried out from January to May 2010 to investigate associations between udder conformation, milk somatic cell count (SCC) and lamb weight. Ewes and lambs were observed at lambing. Ewe health and teat condition and lamb health and weight were recorded on 4 – 5 further occasions at 14 day intervals. At each observation a milk sample was collected from each udder half for somatic cell counting. Two weeks after lambing ewe udder conformation and teat placement were scored. Lower lamb weight was associated with ewe SCC > 400,000 cells/ml (-0.73 kg), a new teat lesion 14 days previously (-0.91 kg), sub - optimal teat position (-1.38 kg), reared in a multiple litter (-1.45 kg), presence of diarrhoea at the examination (-1.19 kg) and reared by a 9 year old ewe compared with a 6 year old ewe (-2.36 kg). Higher lamb weight was associated with increasing lamb age (0.21 kg/day), increasing birth weight (1.65 kg/kg at birth) and increasing number of days the ewe was given supplementary feed before lambing (0.06 kg/day). Higher udder half SCC was associated with pendulous udders (9.6% increase in SCC/cm drop) and greater total cross-sectional area of the teats (7.2% increase of SCC/cm^2). Lower somatic cell counts were associated with a heavier mean litter weight (6.7% decrease in SCC/kg). Linear, quadratic and cubic terms for days in lactation were also significant. We conclude that poor udder and teat conformation is associated with higher levels of intramammary infection, as indicated by raised somatic cell count and that both physical attributes of the udder and SCC are linked to lamb growth suggesting that selection of ewes with better udder and teat conformation would reduce intramammary infection and increase lamb growth rate.

Key words: suckler ewe, udder conformation, milk somatic cell count, lamb weight, mixed effect models, cohort study

INTRODUCTION

In dairy cattle there is strong evidence that poor udder conformation is associated with raised somatic cell count and an increased incidence of clinical mastitis (reviewed by Seykora and McDaniel 1985). In dairy sheep, linear appraisal of udder traits has been developed (Casu et al., 2006; de la Fuente et al., 1996; Marie-Etancelin et al., 2005). Casu et al. (2010) studied a flock of 900 pedigree ewes with historical data and known family relationships and detected a genetic correlation between udder conformation and mastitis and SCC with a heritability of 0.4. Currently, some European dairy sheep breeds include udder traits in their breeding programs, mainly with the aim of improving machine milking ability (Casu et al., 2006; Casu et al., 2010; Marie-Etancelin et al., 2005) but to date no work has been done on the role of udder conformation in intramammary infection and lamb growth in suckler sheep.

Mastitis in sheep causes economic losses from costs of treatment, ewe replacements, and reduced milk production (Albenzio et al., 2002). In suckler sheep, reduction in milk yield reduces lamb growth rate: lambs reared by ewes experimentally infected with *Staphylococcus simulans* to induce subclinical infection had significantly lower growth rates to 52 days of age than lambs reared by unchallenged ewes (Fthenakis and Jones, 1990). In observational studies clinical mastitis (Larsgard and Vaabenoe, 1993) and subclinical mastitis (either defined by presence of bacteria or positive CMT) have been associated with reduced growth rate of lambs (Moroni et al., 2007; Arsenault et al., 2008) although supplementary feed negated this association (Keisler et al., 1992).

To date there has been no study of the associations between udder conformation and intramammary infection and their impact on lamb weight in suckler ewes. Therefore the aims of the current study were to investigate the relationships between udder conformation, SCC and lamb weight in a cohort study of suckler ewes.

MATERIALS AND METHODS

Study farm and ewe selection

A farm in Shropshire, England was convenience selected on willingness to participate, management of ewes in separate age groups and handling facilities that enabled longitudinal observation of ewes and lambs. A total of 78 ewes were enrolled into the study in December 2009: the study group comprised 20 2 year old Suffolk mules, 20 6 year old Suffolk mules and 38 9 year old North Country mules.

Collection of ewe and lamb data

In February 2010, one month before lambing was due to start, ewes selected for study were examined and their ear tag number and body condition score (BCS) (Defra PB1875, undated) were recorded. Within 12 - 72 hours of lambing, each ewe and litter was examined whilst in an individual lambing pen. Each lamb was identified with an ear tag and all clinical abnormalities were recorded. Lambs were weighed using an ISO 9001:2008 assured hanging scale with 0.1 kg calibrations (Salter 235 - 6S) and their sex and litter size recorded. The BCS of each ewe was recorded. Whilst the ewe was in pelvic recumbency, the udder was examined and all visible and palpable abnormalities including scars on the udder and teats were recorded. Teat lesion type, depth, position and location were recorded and later classified as traumatic or non - traumatic. Traumatic teat lesions included bite wounds, tears and chapping. Non - traumatic lesions included proliferative skin lesions, warts and spots. A milk sample was collected from each udder half.

After lambing, ewes were managed in four groups categorised by age, and litter size. The groups were 2 and 6 year old Suffolk mules with single lambs, 2 and 6 year old Suffolk mules with multiple lambs, 9 year old North Country mules with single lambs and 9 year old North Country mules with multiple lambs. Ewes and lambs were examined every 14 days from lambing until lambs were 8 - 10 weeks old. Each group was brought in from the fields to a sheltered handling facility when examined. At each examination, lambs were weighed in a calibrated weigh crate and ewes were cast in pelvic recumbency in a cradle. Ewes and lambs were examined and milk samples collected. At the second examination only, detailed measurements of the udder were made and the udder conformation was scored using a nine point scoring system developed by Casu etal.(2006) with the ewe standing and in pelvic recumbency. In addition, the length and width of the teat were measured. Milk samples for somatic cell counting were diluted with phosphate buffered saline to a volume of 20ml at the University of Warwick to facilitate automated somatic cell counting. These were kept chilled and transported within 1 week of collection to an external laboratory (QMMS Ltd, Somerset, UK) for analysis using an automated combined spectrometer and flow cytometer (Delta CombiScope FTIR (Delta Instruments B.V., Drachten, Netherlands)). The results from somatic cell counting were corrected according to the dilutions used.

Data storage and analysis

A database was constructed in Microsoft Access 2007 into which observation date, ewe ID, BCS, SCC, udder conformation scores and measurements and abnormalities of the udder, teat and milk were stored. From the width of the teat measurement the total teat cross sectional area was calculated assuming each teat was circular in cross section, with the teat width the diameter (d) of the circle and so the cross sectional area of each teat was ($0.5(d\pi^2)$). This was summed to give the total cross sectional area of the teats. A second linked sheet was used to store lamb ID, litter size, lamb weight and whether lambs were thin, had diarrhoea or had scabs around their muzzle. Descriptive analysis was performed in Stata 10 (StatCorp LP, Texas). The somatic cell count data were log10 transformed and the normality of both outcome variables was assessed. Strata were merged where adjacent categories had less than six observations. Explanatory variables observed repeatedly were plotted over time categorised by ewe age and litter size. Log somatic cell count was categorised into quintiles to investigate the linearity between SCC and lamb weight.

Two three - level multivariable linear regression models were constructed in MLwiN 2.11 (Rasbash et al., 2005); the first with lamb weight (kg) as the continuous outcome variable with ewe, lamb and observation as random effects levels 3, 2 and 1; the second with $\log_{10}$ SCC (cells/ml) as the continuous outcome variable with ewe, udder half and observation as random effects levels 3, 2 and 1. Each model took the general structure:

$$y_{ijk}=\beta_0+ \beta x_k + \beta x_{jk} + \beta x_{ijk} + v_k + u_{jk} + e_{ijk}$$

where y_{ijk} is the continuous outcome variable and βx is a series of vectors of fixed effects that vary at *k*, *jk*, and *ijk* with variance estimates at, v_k u_{jk} e_{ijk}. The independent variables were tested in the model using a manual forward stepwise selection process. Significance was set at 0.05. Where similar and highly correlated explanatory variables were tested and significant in the multivariable model, the variable that most reduced the log likelihood per degree of freedom was retained.

RESULTS

From the 78 ewes enrolled, 73 lambed over a period of 49 days. Sixty - seven ewes that had at least one lamb that survived for a minimum of three observations and for which SCC results were available for at least three occasions from at least one udder half were included in the analysis. Four ewes were lost to follow up due to death, including one ewe with acute clinical mastitis after lambing. A further two ewes were omitted from the analysis due to insufficient somatic cell counts or lamb weights. One ewe developed acute clinical mastitis 45 days after lambing; data from this ewe and her lambs were included in the analysis until day 45. Of the 67 ewes that were included in the analysis, 36 reared one lamb, 31 reared twins and one reared triplets; two ewes had one foster lamb each. There were 101 lambs that were followed, twins and triplets were grouped as multiples. Fifty-nine lambs were male and 42 female, 16 lambs had scabby skin lesions on their muzzles, 25 had diarrhoea and 29 were visibly thin on at least one occasion. Forty - one ewes had at least one teat lesion. Younger ewes had a higher BCS than older ewes and ewes rearing one lamb had a higher BCS than ewes rearing multiples. Summary statistics are presented in Tables 1 and 2.

There were 592 observations of 101 lambs between birth and 10 weeks of age. At the first observation of lambs the mean age was 1.6 days and mean weight was 5.3 kg. There were 568 SCC measurements from 67 ewes: $\log_{10}$SCC ranged from 4.45 to 7.65 with a mean $\log_{10}$SCC 5.45 and arithmetic mean SCC of 281, 000 cells/ml. The mean $\log_{10}$SCC was significantly higher ($p<0.05$) in the first week after lambing compared with subsequent weeks with a general pattern of decreasing SCC in the first four weeks of lactation followed by a trend of gradual increase five to ten weeks after lambing.

A list of all variables assessed in univariable analysis of the continuous outcomes of lamb weight (kg) and $\log_{10}$SCC respectively that were not in the final multivariable models are presented in Tables 3 and 5. Log_{10}SCC in left and right udder halves was highly correlated ($r= 0.87$). Ewe age was positively correlated with breed ($r = 0.82$), and negatively correlated with BCS ($r = - 0.62$), BCS and breed were negatively correlated ($r= - 0.64$).

The peak incidence of traumatic teat lesions occurred 3 - 4 weeks after lambing (Cooper et al., personal communication), the incidence then decreased gradually until 9 - 10 weeks after lambing. The incidence of non-traumatic lesions gradually increased until week 9 - 10 after lambing.

Multivariable analyses of lamb weight (Table 4)

Lower lamb weight at an examination was associated ($P < 0.05$) with ewe mean SCC > 400,000 cells/ml (-0.73 kg), new teat lesion 14 days previously (-0.91 kg), suboptimal teat position (-1.38 kg), reared in a multiple litter (-1.45 kg), presence of diarrhoea at the examination (-1.19 kg) and reared by a 9 year old ewe compared with a 6 year old ewe (-2.36 kg). Higher lamb weight was associated ($P < 0.05$) with increasing lamb age (0.21 kg/day), increasing birth weight (1.65 kg/kg) and increasing number of days the ewe was given supplementary feed before lambing (0.06 kg/day). The model fit was good (data not shown).

Multivariable analysis of log somatic cell count (Table 6)

Higher half SCC was associated with more pendulous udders (9.6% increase in SCC/cm drop) and greater total cross - sectional area of the teats (7.2% increase of SCC/cm^2). Lower somatic cell counts were associated with heavier mean litter weight (6.7% decrease in SCC/kg). Linear, quadratic and cubic terms for days in lactation were also significant. The model fit was good (data not shown).

DISCUSSION

This is the first longitudinal study to investigate udder and teat conformation and their impacts on lamb weight and somatic cell count in suckler ewes.

A combination of linear scores and measurement in centimetres was used to evaluate udder and teat conformation. Similar approaches have been employed to assess udder conformation in dairy ewes (de la Fuente et al., 1996; Casu et al., 2006 and 2010). Casu et al. (2006) reported that the system developed to score dairy ewe udder conformation had fairly high levels of repeatability across lactations and, assuming that this is so for suckler ewes, then the associations found in the current study should be affecting lamb weight and SCC rather than a result of these variables. Suckler ewes are with their lambs 24 hours per day and it is not possible to measure milk yield directly. We have assumed that after lamb weight was adjusted for known confounders, such as litter size and birth weight, lamb weight is dependent on ewe milk production, particularly in these young lambs with no rumen and no other source of food. Other authors have also used lamb weight as a measure of milk production and linked this to clinical and subclinical mastitis (Larsgard and Vaabenoe, 1993; Moroni et al., 2007; Arsenault et al., 2008).

Because of the low number of observations of teat placement in the current study in the most medial and most lateral categories in the nine point scale, categories were merged into 5 classes of approximately equal number of observations. Ewes with a teat placement of score 5 (Figure 1) reared significantly heavier lambs than ewes with more medial or more lateral teat positions. This suggests that this is an optimum teat position that allows the lamb to suckle. Other teat positions were also associated with a higher propensity for teat lesions (Cooper et al., personal communication). Traumatic teat lesions were associated with a lower lamb weight 14 days later. This is most likely because a fresh teat lesion such as a bite would result in a ewe preventing her lamb(s) from suckling until the wound is healing. The lower lamb weight and increased risk of teat lesions might indicate that lambs are not able to latch on to the teat efficiently or that milk delivery from the teat is impeded when the teat position is too lateral or too medial (Figure 1) so lambs take in less milk when suckling. No other udder conformation variables were associated with lamb weight. Teat lesions of either type were not significantly associated with a change in half SCC (Table 6). This was also reported by Watkins et al. (1991) and might indicate that teat lesions do not increase the risk of bacterial invasion of the udder. In contrast, pendulous udders were associated with an increase in SCC. Casu et al. (2010) reported that dairy ewes with pendulous udders had higher SCC. It may be that pendulous udders are more exposed to environmental contamination, thus increasing challenge with environmental pathogens and an associated increase in SCC. In addition in the current study, total cross - sectional area of the teats was positively associated with SCC. This may be because a bigger teat cistern may facilitate a greater volume of residual milk in the teat in which pathogens may multiply or because such teats have less patent teat sphincters which would increase the risk of bacterial entry into the teat canal.

A study over seven years from one University in the United States (Paape et al., 2007) reported that composite SCC from dairy cows and dairy goats, but not dairy ewes, increased with parity. They also reported, as in the current study, that composite SCC decreased in the second month of lactation, probably due to the dilution effect of increased milk yield, and then rose again. In contrast to Paape et al. (2007) Lafi et al. (2006) reported that multiparous ewes had a significantly higher SCC than primiparous ewes in a study of 46 dairy Awassi flocks. Watkins etal.(1991) reported that the prevalence of subclinical mastitis increased with age in suckler ewes in a longitudinal study of subclinical mastitis in 358 ewes from 7 flocks in England. It is probable that older ewes have been exposed to more pathogens over the course of numerous lactations which might explain the higher SCC in older ewes in the current study.

BCS and age of ewe were significantly correlated (r = 0.62), thus the association between ewe BCS and lamb weight independent of ewes age was difficult to assess in the current study. There was a significant effect of age of ewe on lamb weight, with lambs reared by 9 year old ewes weighing on average 2.36 kg less than lambs reared by 6 year old ewes. Al-Sabbagh et al. (1995) reported a lower total weaning weight of lambs reared by 7 year old ewes compared with 4 year olds, despite a higher total birth weight of lambs in ewes of 7 years. Since subclinical udder infection has been associated with decreased milk production (Saratsis et al., 1999; Gonzalo et al., 2002), it may be that milk production or perhaps milk quality is more likely to be suboptimal in old ewes. Lamb weight was marginally (10% significance) lower in primiparous ewes than 6 year olds in the current study. It could be argued that middle aged ewes may be under less metabolic strain because younger ewes are still growing themselves.

Whilst the study was small the detail is useful and can inform future investigations and programmes considering selection of ewes. Lamb production may be improved by management choices employed by the sheep farmer. For example, removing older ewes from the flock would give a younger flock more able to rear lambs from milk and grass. Providing sufficient feed to ewes to optimise body condition during gestation and maximise milk production during lactation would reduce the risks of poor BS on lamb growth and ewe SCC. Supplementary feed to lambs reared by older ewes would increase lamb growth rate and reduce demand on the ewe. In the future it might be possible to improve udder shape and teat position through genetic selection of suckler ewes.

CONCLUSIONS

This study is the first to report the impact of poor udder and teat conformation on the growth of lambs and sub clinical infection in suckler ewes. There were associations between high somatic cell count and poor udder and teat conformation, indicating that ewes with poor udder conformation were more likely to have high SCC. Lamb growth rate was slower when ewes had high SCC, indicating lower milk production from such ewes, possibly because of damage to the mammary parenchyma from bacterial infection. Lamb growth rate was also lower when udder and teat conformation was poor, possibly indicating that these lambs could not feed efficiently from ewes with poor conformation or that udder conformation affected milk production. We conclude that there are hidden production losses from subclinical intramammary infection and poor udder shape in this flock of ewes.

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Table 1. Summary statistics for continuous explanatory variables

Continuous variables	Min	Max	Mean	Std. Dev.	n
Lamb age (days)	0	102	38.12	27.95	592
Birth weight (kg)	2.30	8.4	5.25	1.25	101
Biweekly lamb weight (kg)	2.30	36.9	13.16	6.83	592
Log SCC[1] left udder-half	4.45	7.34	5.38	0.52	278
Log SCC right udder-half	4.53	7.65	5.52	0.64	290
Log SCC both udder-halves	4.45	7.65	5.45	0.59	568
Days ewe fed concentrates before lambing	37	85	61.66	9.68	67
Days BCS[2] before lambing	8	56	32.66	9.68	67
Udder drop (cm)	11.40	24.10	16.83	2.75	64
Width at base of udder (cm)	7.90	23.0	17.26	2.77	65
Left teat length (cm)	2.50	5.00	3.38	0.56	66
Right teat length (cm)	2.50	5.10	3.55	0.58	66
Left teat width (cm)	1.00	2.50	2.07	0.34	66
Right teat width (cm)	1.00	3.0	2.05	0.43	66
Sum cross sectional area of both teats (cm^2)	7.50	15.00	11.06	1.50	66

[1] Somatic cell count
[2] Body condition score

Table 2. Summary statistics for categorical explanatory variables

Categorical variables	Number of observations	denominator	Percent of observations
Ewe age (at lambing)			
2yr	19	67	28.36
6yr	19	67	28.36
9yr	29	67	43.28
Litter size			
single	35	67	52.24
Multiple	32	67	46.42
Teat placement scores			
1 - 3 (most medial)	12	64	18.75
4	14	64	21.88
5	13	64	20.31
6	12	64	18.75
7 - 9 (most lateral)	13	64	20.31
Udder separation (score)			
1 (minimum separation)	22	64	34.38
2	20	64	31.25
3	14	64	21.88
4 - 9 (maximum separation)	8	64	12.50
Udder drop score			
1 (greatest drop) to 5	17	65	26.15
6	24	65	36.92
7 to 9 (least drop)	24	65	36.92
Wool on udder			
No	53	66	80.3
Yes	13	66	19.70
Udder contaminated with faeces or mud at examination	29	401	6.25
Clean	30	65	46.18
Moderately dirty	17	65	26.15
Very dirty	18	65	27.69
Water availability at lambing			
Unrestricted	20	65	30.77
Restricted	27	65	41.54
No water available	18	65	27.69
BCS[1] before lambing (4 categories)			
2 or less	8	67	11.94
2.5	24	67	35.82
3	20	67	29.85
3.5 or more	15	67	22.39

Table 3 continued. Summary statistics for categorical explanatory variables

Categorical variables	Number of observations	Denominator	Percent of observations
BCS at biweekly observation			
1.5 or less	24	401	0.06
2	70	401	0.17
2.5	97	401	0.24
3	120	401	0.30
3.5	56	401	0.14
3.5 or more	34	401	0.08
Ewe had teat lesion on at least one teat at any point in study	49	67	73.13
Teat had lesion at any point in study	87	125	69.60
Teat had traumatic teat lesion on at any point in study	67	125	53.60
Teat had a non-traumatic lesion at any point in study	55	125	44.00
Traumatic lesion on either teat at examination	87	566	15.37
Non traumatic lesion on either teat at examination	51	566	9.01
Lesion at or near teat orifice at examination	163	568	28.70
Pustule or papule on teat at examination	31	568	5.46
Lamb had diarrhoea	39	591	6.60
Lamb had suspected orf	19	592	3.21
Lamb visibly or palpably thin	33	591	5.58

[1]Body condition score

Table 3. Univariable analysis of variables associated with lamb weight not in the final mixed effects model (Table 4) in 101 lambs from 67 ewes in one flock

Variable	Coefficient	95% Confidence Intervals lower	upper
Udder drop (cm)	-0.12	-0.40	0.16
Left teat length (cm)	-0.76	-2.12	0.60
Left teat width (cm)	-0.70	-2.95	1.56
Right teat length (cm)	-0.35	-1.68	0.98
Right teat width (cm)	0.29	-1.49	2.08
Lamb had suspected orf	5.19	2.17	8.22
Breed North Country mule vs Suffolk mule	-1.60	-3.11	0.09
BCS[1] before lambing ≤2	Reference		
2.5	-0.19	-2.83	2.44
3	0.20	-2.46	2.86
≥3.5	1.93	-0.88	4.74
BCS at examination≤1.5	Reference		
2	3.06	0.55	5.56
2.5	1.90	-0.63	4.44
3	5.47	2.96	7.99
≥3.5	2.56	-0.12	5.24
Udder separation score			
1 (minimum separation)	-1.75	-6.38	2.87
2	-3.07	-7.71	1.56
3	-1.08	-5.79	3.63
4	Reference		
5	1.91	-3.63	7.44
6	-0.89	-6.59	4.81
7	-1.85	-9.12	5.43
8 to 9 (maximum separation)	No observations		
Udder drop score			
1 (maximum drop) to 5	Reference		
6	0.18	-1.74	2.10
7 to 9 (minimum drop)	-0.09	-2.03	1.86
Teat placement score			
1 (most medial) to 3	-0.01	-2.06	2.04
4 to 6	Reference		
7 to 9 (most lateral)	0.41	-1.48	2.30
Udder contaminated at examination	-0.85	-3.10	1.41
Udder contaminated at previous examination	1.43	-0.79	3.64
Wool on udder	-0.85	-2.65	0.96
Bedding at lambing			
clean	Reference		
moderately dirty	1.49	-0.35	3.32

very dirty	-0.54	-2.32	1.23
Water availability at lambing			
unrestricted	Reference		
restricted	-0.39	-2.15	1.36
no water available	0.89	-1.14	2.92
Teat lesion on either teat at examination	2.95	1.89	4.00
Traumatic teat lesion on either teat at examination	1.92	0.73	3.11
Non-traumatic teat lesion on either teat at previous examination	3.45	2.03	4.87
Teat lesion on either teat at previous examination	3.25	2.13	4.37

[1]Body condition score

Table 4. Mixed effects model of factors associated with lamb weight in 101 lambs born to 67 ewes on one farm

Variables	Univariable mean	95% CI Lower	95% CI Upper	Multivariable mean	95% CI Lower	95% CI Upper
Intercept	13.41	12.64	14.12	0.911	-2.43	4.25
Lamb age (days)	0.21	0.20	0.21	0.21	0.20	0.22
Birth weight (kg)	1.91	1.50	2.32	1.65	1.31	2.00
Concentrate feed before lambing (days)	0.01	-0.07	0.10	0.06	0.01	0.10
Ewe age						
2yr	-0.59	-2.51	1.33	-0.17	-1.28	0.93
6yr	Reference			Reference		
9yr	-1.87	-3.61	-0.12	-2.36	-3.31	-1.40
Female vs male lamb	-0.85	-2.13	0.43	0.34	-0.22	0.90
Multiple vs single lamb	-3.70	-4.73	-2.67	-1.45	-2.31	-0.58
Presence of diarrhoea	4.11	1.94	6.28	-1.19	-1.93	-0.45
SCC[1]						
1st quintile	Reference			Reference		
2nd quintile	-1.09	-2.62	0.45	-0.73	-1.33	-0.13
3rd quintile	-2.03	-3.58	-0.49	-0.48	-1.11	0.14
4th quintile	-4.03	-5.58	-2.47	-1.39	-2.07	-0.71
5th quintile	-6.70	-8.30	-5.08	-1.33	-2.17	-0.50
Teat placement scores						
1 to 3 (medial)	-0.21	-2.70	2.29	-1.38	-2.48	-0.28
4	0.20	-2.19	2.59	-0.20	-1.27	0.88
5	ref			Ref		
6	-0.82	-3.27	1.63	-1.47	-2.58	-0.36
7 to 9 (lateral)	0.22	-2.15	2.59	-0.16	-1.35	1.04
Non traumatic teat lesion at examination	3.27	1.93	4.61	-0.48	-1.03	0.06
Traumatic teat lesion at previous examination	2.33	1.07	3.60	-0.91	-1.41	-0.41
	Variance	95% CI		Variance	95% CI	
Between		Lower	Upper		Lower	Upper
ewe	5.11	1.68	8.55	1.093	0.39	1.79
lamb	0.00	0.00	0.00	0.300	-0.18	0.78
examination	41.77	36.73	46.81	2.14	1.74	2.54

[1]Somatic cell count, -2*Log likelihood=1219.233 (312 out of 592 cases used)

Table 5. Variables associated with log_{10}somatic cell count (n=568) but not included in multivariable model

Variable	Mean SCC	95% Confidence Interval Lower	Upper
Width of base of udder (cm)	0.02	-0.01	0.05
North of England mule vs Suffolk mule as ref*	0.27	0.09	0.44
Multiple vs single lamb	0.07	-0.11	0.25
Diarrhoea in at least one lamb*	-0.17	-0.32	-0.02
Suspected orf in at least one lamb	-0.18	-0.38	0.03
At least one lamb thin	-0.01	-0.18	0.17
Udder separation score*			
1 (minimum separation)	Ref		
2	-0.15	-0.37	0.08
3	-0.06	-0.31	0.18
4 to 9 (maximum separation)	-0.37	-0.67	-0.08
Udder drop score			
1 (maximum drop) to 5	Reference		
6	-0.23	-0.44	-0.01
7 to 9 (minimum drop)	-0.32	-0.54	-0.11
BCS[1] before lambing*			
2 or less	Reference		
2.5	-0.37	-0.67	-0.07
3	-0.41	-0.71	-0.11
3.5 or more	-0.52	-0.83	-0.20
BCS at examination *			
1.5 or less	Reference		
2	-0.16	-0.39	0.08
2.5	-0.27	-0.51	-0.03
3	-0.43	-0.68	-0.19
3.5 or more	-0.37	-0.62	-0.11
Teat placement score			
1 (most medial) to 3	0.08	-0.16	0.33
4 to 6	Reference		
7 to 9 (most lateral)	0.25	0.02	0.49
Traumatic teat lesion at examination*	-0.14	-0.25	-0.02
Traumatic teat lesion at previous examination	-0.04	-0.15	0.07
Non-traumatic teat lesion at examination*	-0.14	-0.29	-0.00
Non-traumatic teat lesion at previous examination*	0.11	-0.03	0.26
Lesion near teat orifice at previous examination	-0.07	-0.15	0.01
Udder contaminated at examination	-0.11	-0.25	0.03
Udder contaminated at previous examination	-0.08	-0.21	0.06
Woolly udder yes vs no	0.01	-0.23	0.24

Table 5 continued. Variables associated with log_{10}somatic cell count (n=568) but not included in multivariable model

Variable	Coefficient	95% Confidence Interval	
		Lower	Upper
Bedding at lambing			
clean	Reference		
moderately dirty	0.11	-0.10	0.33
very dirty	0.13	-0.09	0.35
Water at lambing			
unrestricted	Reference		
restricted	-0.02	-0.24	0.20
no water available	-0.02	-0.26	0.23

[1]Body condition score

Table 6. Multivariable model of $\log_{10}$ somatic cell count of udder halves of 67 ewes from one flock

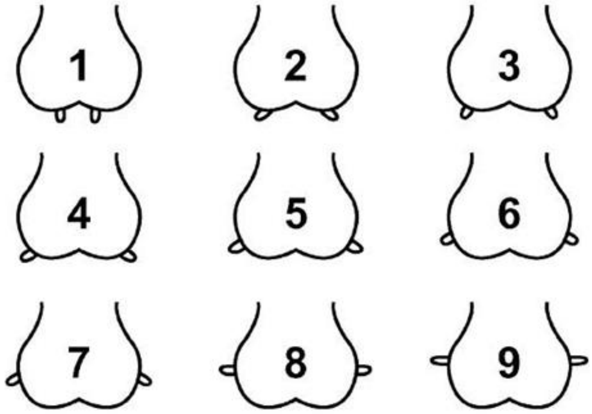
Variable	Univariable coefficient	95% CI lower	95% CI upper	Multivariable coefficient	95% CI lower	95% CI upper
Intercept	5.48	5.39	5.57	4.85	4.29	5.42
Days in lactation	-0.01	-0.01	-0.01	-0.03	-0.05	-0.02
Days in lactation^2	-7.08×10^{-5}	-9.68×10^{-5}	-4.48×10^{-5}	9.31×10^{-4}	4.57×10^{-4}	1.41×10^{-3}
Days in lactation^3	-8.30×10^{-7}	-1.24×10^{-6}	-4.20×10^{-7}	-6.74×10^{-6}	-1.52×10^{-5}	-1.96×10^{-6}
Mean litter weight at observation (kg)	-0.03	-0.04	-0.03	-0.03	-0.05	-0.01
Udder drop (cm)	0.06	0.03	0.09	0.04	0.01	0.07
Sum cross sectional area of teats (cm^2)	0.03	0.01	0.05	0.03	0.01	0.05
Lesion at teat orifice at examination	-0.20	-0.29	-0.11	-0.11	-0.19	-0.03
2 yr old, BCS[1] ≥3	Reference			Reference		
6 yr old, BCS = 3	0.09	-0.09	0.26	0.08	-0.08	0.24
6 yr old, BCS = 2.5	0.10	-0.11	0.32	0.08	-0.12	0.29
6 yr old, BCS = 2	0.27	-0.12	0.65	0.35	-0.08	0.78
6 yr old, BCS ≤ 1.5	0.94	0.41	1.48	0.70	0.23	1.17
9 yr old, BCS = 3	0.14	-0.17	0.45	0.12	-0.15	0.39
9 yr old, BCS = 2.5	0.24	0.05	0.44	0.19	0.00	0.37
9 yr old, BCS = 2	0.30	0.11	0.49	0.20	0.01	0.38
9 yr old, BCS ≤ 1.5	0.34	0.06	0.62	0.27	0.02	0.52
	Variance	95% CI lower	95% CI upper	Variance	95% CI lower	95% CI upper
Between ewe	0.07	0.02	0.13	0.02	-0.02	0.06
Between udder-half	0.09	0.04	0.14	0.11	0.06	0.15
Between examination	0.19	0.16	0.21	0.13	0.12	0.15
2*Log likelihood=646.116 (539 out of 568 cases)						

[1]Body condition score, CI = confidence interval

Table 7. Correlations (r>0.5) of explanatory variables in multivariable models

Variable	Correlated variables (correlation coefficient)
Lamb age (days)	Non traumatic lesion on either teat at examination (-0.6) Traumatic lesion on either teat at examination (-0.6)
Udder drop (cm)	Udder drop score (0.8) Udder width at base (cm) (0.7)
Total cross sectional area of both teats (cm^2)	Udder drop score (0.7) Udder drop (cm) (0.6) Teat placement (0.6) Separation of udder halves (0.6) Udder width at base (cm) (0.7)
Ewe body condition score	Breed of ewe (0.8) Ewe body condition score before lambing (0.6)
Ewe age	BCS at examination (0.63) Breed of ewe (0.8)
Mean Log SCC	Non traumatic lesion on either teat at examination (-0.6) Traumatic lesion on either teat at examination (-0.6) Length of teat (cm) (0.8)
Teat placement scores (1(most medial) to 3, 4, 5, 6, 7 to 9 (most lateral))	Udder drop score Udder drop measurement (cm) (0.9) Udder width at base (cm) (0.7) Separation of udder halves score (1)

Figure 1. Teat placement scores 1 (most medial) to 9 (most lateral)



(source Casu et al., 2006)