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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 1 farm was carried out from January to May 2010 to investigate associations between udder conformation, udder half 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 to 5 further occasions at 14-d 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. Low lamb weight was associated with ewe SCC >400,000 cells/mL (−0.73 kg), a new teat lesion 14 d previously (−0.91 kg), suboptimal teat position (−1.38 kg), rearing in a multiple litter (−1.45 kg), presence of diarrhea at the examination (−1.19 kg), and rearing by a 9-yr-old ewe compared with a 6-yr-old ewe (−2.36 kg). High lamb weight was associated with increasing lamb age (0.21 kg/d), 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/d). High udder half SCC was associated with pendulous udders (9.6% increase in SCC/cm of drop) and greater total cross-sectional area of the teats (7.2% increase of SCC/cm^2). Low SCC 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 are associated with high levels of intramammary infection, as indicated by increased SCC and that both physical attributes of the udder and SCC are linked to lamb growth, suggesting that selection of suckler 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

INTRODUCTION

In dairy cattle, strong evidence exists that poor udder conformation is associated with raised SCC and an increased incidence of clinical mastitis (reviewed by Seykora and McDaniel, 1985). In dairy sheep, a linear appraisal of udder traits has been developed (de la Fuente et al., 1996; Marie-Etancelin et al., 2005; Casu et al., 2006). 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 (Marie-Etancelin et al., 2005; Casu et al., 2006; Casu et al., 2010) but to date no work has been done on the role of udder conformation in IMI 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 d 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 to lambs negated this association (Keisler et al., 1992), suggesting that these IMI reduce milk production.

To date, no study has been done on the associations between udder conformation and IMI and their effect

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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, United Kingdom, 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. Seventy-eight ewes were enrolled into the study in December 2009: the study group comprised twenty 2-yr-old Suffolk mules, twenty 6-yr-old Suffolk mules, and thirty-eight 9-yr-old North Country mules.

Collection of Ewe and Lamb Data

In February 2010, 1 mo before lambing was due to start, ewes selected for study were examined and their ear tag numbers and BCS (Defra PB1875, undated) were recorded. Within 12 to 72 h of lambing, each ewe and litter was examined while still in an individual lambing pen. Each lamb was identified with an ear tag and all clinical abnormalities were recorded. Lambs were weighed using an International Organization for Standardization (ISO, 2008) assured hanging scale with 0.1-kg calibrations (Salter 235-6S; Salter Brecknell, Smethwick, West Midlands, UK) and their sex and litter size recorded. The BCS of each ewe was recorded. While 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 nontraumatic. Traumatic teat lesions included bite wounds, tears and chapping. Nontraumatic lesions included proliferative skin lesions, warts, and pustules. A milk sample was collected from each udder half.

After lambing, ewes were managed in 4 groups, categorized by age and litter size. The groups were 2- and 6-yr-old Suffolk mules with single lambs, 2- and 6-yr-old Suffolk mules with multiple lambs, 9-yr-old North Country mules with single lambs, and 9-yr-old North Country mules with multiple lambs. Ewes and lambs were examined every 14 d from lambing until lambs were 8 to 10 wk 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 9-point scoring system developed by Casu et al. (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 PBS to a volume of 20 mL at the University of Warwick (Coventry, UK) to facilitate automated somatic cell counting. These were kept chilled and transported within 1 wk 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, the 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 (Microsoft Corp., Redmond, WA) into which observation date, ewe identification, 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 being the diameter (d) of the circle, and so the cross-sectional area of each teat was $0.5(\pi d^2)$. This was summed to give the total cross-sectional area of the teats. A second linked sheet was used to store lamb identification, litter size, lamb weight, and whether lambs were thin, had diarrhea, or had scabs around their muzzle.

Descriptive analysis was performed in Stata 10 (StataCorp LP, College Station, TX). The SCC data were common logarithm ($\log_{10}$) transformed and the normality of both outcome variables was assessed. Strata were merged where adjacent categories had less than 6 observations. Explanatory variables observed repeatedly were plotted over time categorized by ewe age and litter size. The logarithm of SCC was categorized into quintiles to investigate the linearity between SCC and lamb weight.

Two 3-level multivariable linear regression models were constructed in MLwiN 2.11 (Rasbash et al., 2009): the first with lamb weight (kg) as the continuous outcome variable with ewe, lamb, and observation as random effects levels 3, 2, and 1; and the second with the common logarithm ($\log_{10}$) of 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 form

$$y_{ijk} = \beta_0 + \boldsymbol{\beta}\mathbf{x}_k + \boldsymbol{\beta}\mathbf{x}_{jk} + \boldsymbol{\beta}\mathbf{x}_{ijk} + v_k + u_{jk} + e_{ijk},$$

where y_{ijk} is the continuous outcome variable, β_0 is the intercept,and $\boldsymbol{\beta}\mathbf{x}$ is a series of vectors of fixed effects that vary at *k, jk*, and *ijk*, with variance estimates at v_k, u_{jk}, and 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 d. Sixty-seven ewes that had at least 1 lamb that survived for a minimum of 3 observations and for which SCC results were available for at least 3 occasions from at least 1 udder half were included in the analysis. Four ewes were lost to follow up due to death, including 1 ewe with acute clinical mastitis after lambing. A further 2 ewes were omitted from the analysis due to insufficient SCC or lamb weights. One ewe developed acute clinical mastitis 45 d after lambing; data from this ewe and her lambs were included in the analysis until d 45. Of the 67 ewes that were included in the analysis, 36 reared 1 lamb, 31 reared twins and 1 reared triplets; 2 ewes had 1 foster lamb each. One hundred and one lambs 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 diarrhea, and 29 were visibly thin on at least 1 occasion. Forty-one ewes had at least 1 teat lesion. Younger ewes had a higher BCS than older ewes and ewes rearing 1 lamb had a higher BCS than ewes rearing multiples. Summary statistics are presented in Tables 1 and 2.

Five hundred and ninety-two observations were made of 101 lambs between birth and 10 wk of age. At the first observation of lambs, the mean age was 1.6 d and mean weight was 5.3 kg. Five hundred and sixty-eight SCC measurements were made on 67 ewes: the common logarithm ($\log_{10}$) of SCC ranged from 4.45 to 7.65 with a mean $\log_{10}$ SCC of 5.45 and arithmetic mean SCC of 281,000 cells/mL. The mean common logarithm ($\log_{10}$) of 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 4 wk of lactation, followed by a trend of gradual increase 5 to 10 wk after lambing.

A list of all variables assessed in the univariable analysis of lamb weight (kg) that were not in the final multivariable model is presented in Table 3. The common logarithm of 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 to 4 wk after lambing (Cooper, 2011), the incidence then decreased gradually until 9 to 10 wk after lambing. The incidence of nontraumatic lesions gradually increased until wk 9 to 10 after lambing.

Multivariable Analyses of Lamb Weight

Lower lamb weight (Table 4) at an examination was associated ($P < 0.05$) with ewe mean SCC >400,000 cells/mL (−0.73 kg), new teat lesion 14 d previously (−0.91 kg), suboptimal teat position (−1.38 kg), rearing in a multiple litter (−1.45 kg), presence of diarrhea at the examination (−1.19 kg), and rearing by a 9-yr-old ewe compared with a 6-yr-old ewe (−2.36 kg). Higher lamb weight was associated ($P < 0.05$) with increasing

Table 1. Summary statistics for continuous explanatory variables

Continuous variable	Minimum	Maximum	Mean	SD	n
Lamb age (d)	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 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 measured 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 teats (cm^2)	7.50	15.00	11.06	1.50	66

Table 2. Summary statistics for categorical explanatory variables

Categorical variable	n	Denominator	% of observations
Ewe age (at lambing, yr)			
2	19	67	28.36
6	19	67	28.36
9	29	67	43.28
Litter size			
Single	35	67	52.24
Multiple	32	67	46.42
Teat placement score			
1 to 3 (most medial)	12	64	18.75
4	14	64	21.88
5	13	64	20.31
6	12	64	18.75
7 to 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 to 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 feces 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 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
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 1 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 at any point in study	67	125	53.60
Teat had a nontraumatic lesion at any point in study	55	125	44.00
Traumatic lesion on either teat at examination	87	566	15.37
Nontraumatic 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 diarrhea	39	591	6.60
Lamb had suspected orf	19	592	3.21
Lamb visibly or palpably thin	33	591	5.58

lamb age (0.21 kg/d), increasing birth weight (1.65 kg/kg) and increasing number of days the ewe was given supplementary feed before lambing (0.06 kg/d). The model fit was good (data not shown).

Multivariable Analysis of the Logarithm of SCC

A list of all variables assessed in the univariable analysis of common logarithm ($\log_{10}$) of SCC that were not

Table 3. Univariable analysis of variables associated with lamb weight not in the final mixed effects model (Table 4) for 101 lambs from 67 ewes in 1 farm

Variable	Coefficient	95% CI Lower	95% CI 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 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
Nontraumatic 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

in the final multivariable model is presented in Table 5. Higher udder half SCC was associated with more pendulous udders (9.6% increase in SCC/cm of drop) and greater total cross-sectional area of the teats (7.2% increase in SCC/cm^2; Table 6). Lower SCC were associated with heavier mean litter weight (6.7% decrease in SCC/kg; Table 6). Linear, quadratic, and cubic terms for days in lactation were also significant. The model fit was good (data not shown). Several significant correlations were found between variables in the 2 multivariable models (Table 7).

DISCUSSION

This is the first longitudinal study to investigate udder and teat conformation and their effects on lamb weight and SCC in suckler ewes. A combination of linear scores and measurement in centimeters was used

Table 4. Mixed effects model of factors associated with lamb weight of 101 lambs born to 67 ewes on 1 farm

Variable	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 (d)	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 (d)	0.01	−0.07	0.10	0.06	0.01	0.10
Ewe age (yr)						
2	−0.59	−2.51	1.33	−0.17	−1.28	0.93
6	Reference			Reference		
9	−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 diarrhea	4.11	1.94	6.28	−1.19	−1.93	−0.45
SCC[1]						
First quintile	Reference			Reference		
Second quintile	−1.09	−2.62	0.45	−0.73	−1.33	−0.13
Third quintile	−2.03	−3.58	−0.49	−0.48	−1.11	0.14
Fourth quintile	−4.03	−5.58	−2.47	−1.39	−2.07	−0.71
Fifth quintile	−6.70	−8.30	−5.08	−1.33	−2.17	−0.50
Teat placement score						
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	Reference			Reference		
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
Nontraumatic 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			Variance		
Between ewe	5.11	1.68	8.55	1.093	0.39	1.79
Between lamb	0.00	0.00	0.00	0.300	−0.18	0.78
Between examination	41.77	36.73	46.81	2.14	1.74	2.54

[1]Somatic cell count: −2 × log-likelihood = 1,219.233 (312 out of 592 cases used).

to evaluate udder and teat conformation. Similar approaches have been used to assess udder conformation in dairy ewes (de la Fuente et al., 1996; Casu et al., 2006, 2010). Casu et al. (2006) reported that the system developed to score dairy ewe udder conformation had high levels of repeatability across lactations and, assuming that this is so for suckler ewes, then the associations in the current study should affect lamb weight and SCC rather than be a result of these variables.

Suckler ewes are with their lambs 24 h per day and it is not possible to measure milk yield directly. We have assumed that lamb weight is primarily dependent on ewe milk production after adjustment for known confounders, such as litter size and birth weight, particularly in young lambs with no rumen and no other source of food. Other authors have also used lamb weight as a proxy for 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 of the 9-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, 2011).

Traumatic teat lesions were associated with a lower lamb weight in the following 14 d. 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 had healed. The lower lamb weight and increased risk of teat lesions in ewes with poor teat position might indicate that lambs were not able to latch on to the teat efficiently or that milk delivery from the teat was impeded when the teat position was too lateral or too medial (Figure 1) so lambs took 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 udder 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.

Table 5. Variables associated with the common logarithm ($\log_{10}$) of SCC (n = 568) but not included in the multivariable model

Variable	Mean SCC	95% CI Lower	95% CI Upper
Width of base of udder (cm)	0.02	−0.01	0.05
North of England mule vs. Suffolk mule as reference[1]	0.27	0.09	0.44
Multiple vs. single lamb	0.07	−0.11	0.25
Diarrhea in at least 1 lamb[1]	−0.17	−0.32	−0.02
Suspected orf in at least 1 lamb	−0.18	−0.38	0.03
At least 1 lamb thin	−0.01	−0.18	0.17
Udder separation score[1]			
1 (minimum separation)	Reference		
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 before lambing[1]			
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]			
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[1]	−0.14	−0.25	−0.02
Traumatic teat lesion at previous examination	−0.04	−0.15	0.07
Nontraumatic teat lesion at examination[1]	−0.14	−0.29	−0.00
Nontraumatic teat lesion at previous examination[1]	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
Bedding at lambing	Coefficient		
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]These variables were also lagged by one observation.

Casu et al. (2010) reported that dairy ewes with pendulous udders also had a 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 7 yr 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 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 (2006) reported that

Table 6. Multivariable model of the common logarithm ($\log_{10}$) of SCC of udder halves of 67 ewes from 1 farm[1]

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 ≥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			Variance		
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

[1]2 × log-likelihood = 646.116 (539 out of 568 cases).

multiparous ewes had a significantly higher SCC than primiparous ewes in a study of 46 dairy Awassi flocks. Watkins et al. (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 the United Kingdom. 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.

The BCS and age of ewe were significantly correlated (r = 0.62; Table 7); thus, the association between ewe BCS and lamb weight independent of ewe age was difficult to assess in the current study. A significant effect of age of ewe on lamb weight was observed, with lambs reared by 9-yr-old ewes weighing, on average, 2.36 kg less than lambs reared by 6-yr-old ewes. Al-Sabbagh et al. (1995) reported a lower total weaning weight of lambs reared by 7-yr-old ewes compared with 4-yr-old

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

Variable	Correlated variables (correlation coefficient)
Lamb age (d)	Nontraumatic 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 BCS	Breed of ewe (0.8) Ewe BCS before lambing (0.6)
Ewe age	BCS at examination (0.63) Breed of ewe (0.8)
Mean log SCC	Nontraumatic 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, and 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)

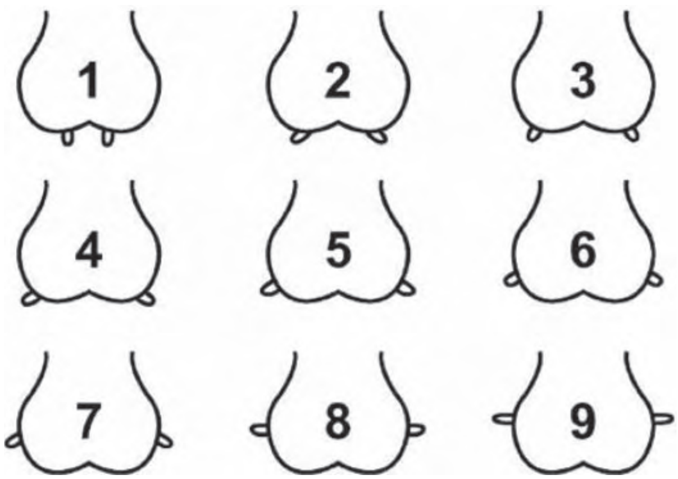

Figure 1. Teat placement scores: 1 (most medial) to 9 (most lateral; source, Casu et al., 2006).

ewes, despite a higher total birth weight of lambs in ewes of 7 yr. As subclinical IMI 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 for primiparous ewes than for 6-yr-old ewes 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.

Although the current study was small, the detail is useful and can inform future investigations and programs considering selection of ewes. Lamb production may be improved by management choices used by the sheep farmer. For example, removing older ewes from the flock would leave a younger flock more able to rear lambs from milk and grass. Providing sufficient feed to ewes to optimize body condition during gestation and maximize milk production during lactation would reduce the risks from poor BCS 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 effect of poor udder and teat conformation on the growth of lambs and subclinical infection in suckler ewes. Associations between high SCC and poor udder and teat conformation were observed, indicating that ewes with poor udder conformation were more likely to have high SCC. Lamb growth weight was lower 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 teat conformation was poor, possibly indicating that these lambs could not feed efficiently from ewes with poor conformation or that teat conformation affected milk production. We conclude that hidden production losses from subclinical IMI and poor udder shape exist in this flock of ewes that, if generalizable, is a considerable hidden cost to farmers producing prime lamb.

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