Clinical characteristics of lameness and potential risk factors in intensive and semi-intensive dairy sheep flocks in Greece

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ABSTRACT. Objectives of the study were to present descriptive epidemiological characteristics of lameness in intensively and semi-intensively reared flocks of Chios-breed dairy sheep in Greece, as well as to identify potential factors that may affect development, severity and duration of the disorder. In total, 1618 ewes in nine flocks were used for assessment of locomotion score and detailed clinical examination, which were performed fortnightly throughout a milking period. Subsequently, two logistic regression models were employed to assess impact of various variables on occurrence and severity of lameness. Mean lameness incidence in the nine flocks under surveillance during the milking period was 6.8% (110 cases in 1618 ewes); between flocks range of the incidence was 0.4%-22.0%. In 48% of the cases, lameness was considered to

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be severe. Foot-rot was found to be the commonest lameness-causing disorder, accounting for 66% of all cases. During the investigation, incidence of lameness in relation to the causing factor was 4.5% for foot-rot, 1% for white line abscesses, 1% for hoof injuries. Farm size, stocking density, parity of the ewes and lambing season were identified as significant risk factors for dairy sheep lameness occurrence. Finally, stocking density was also found to affect lameness severity.

**Keywords:** Chios breed, dairy sheep, lameness, risk factors

**INTRODUCTION**

Lameness is a term used to describe a broad spectrum of locomotion disorders that result in gait abnormalities or in conditions where weight bearing by one or more limbs is compromised. In sheep, lameness is predominantly associated with hoof lesions. To date, research has focused on foot-rot, interdigital dermatitis and, more recently, contagious ovine digital dermatitis and was carried out in meat or wool producing breeds (Winter, 2004; 2009; Wassink et al., 2010; Hodgkinson, 2010). Studies have indicated a strong negative effect of lameness on animal welfare, production output (meat, wool), and reproduction efficiency (Stewart et al., 1984; Marshall et al., 1991; Eze, 2002). Other lameness-causing disorders of sheep, such as white line disease, white line abscesses and pedal joint abscesses have not been thoroughly investigated (Conington et al., 2010).

There is a paucity of relevant studies in dairy sheep. Nevertheless, lameness can be of particular importance for dairy sheep around the world. A recent study performed in Chios-breed sheep indicated that lameness was associated with a 20% reduction in milk yield (Gelasakis et al., 2010a). Descriptive epidemiology studies and potential risk factors assessments for lameness have not been carried out in dairy sheep farms. However, there are distinct differences in husbandry practices between meat and dairy sheep production systems and these may contribute to development of lameness related disorders. Moreover, environmental and climatic factors may also be of importance; within Europe, meat-producing sheep are farmed mainly in the north of the continent, whilst dairy sheep are mostly farmed in more southern and para-Mediterranean countries.

Objectives of this work were to present descriptive epidemiological characteristics of lameness in intensive and semi-intensive Chios-breed dairy sheep farms in Greece, as well as to identify potential risk factors for development and severity of the disorder.
MATERIALS AND METHODS
On-farm investigation

In a previously conducted study, 66 Chios dairy sheep farms were surveyed. The collected data and the produced typology of the studied farms have been previously described by Gelasakis et al. (2010b, 2012). For the needs of the present study, k-means cluster analysis (Steinley, 2006) was used for the selection of a representative sample of these 66 farms. Flock size, stocking density and access to pasture were the grouping factors. Flock size was determined by the number of ewes in the farm, stocking density was defined as the available area (m²) per ewe inside the sheep shed and access to pasture was defined as grazing or zero-grazing. The farms were assigned into eight clusters, of which three were recognised as dominant (comprising ≥10 farms). Three farms from each dominant cluster were randomly selected for further investigation. In total, nine farms, comprised 1,618 ewes, were selected. Data regarding parity number, age at lambing and date of lambing were obtained for these farms.

Each of the nine farms was visited by the principal author (AIG) every fortnight throughout a milking period (after weaning of lambs until cessation of lactation and onset of dry period), from January to July 2008. A designated single line passageway was constructed in each farm to facilitate observation of locomotion of individual ewes on their way to the milking parlour, enabling the assessment of presence and severity of lameness. On each visit, each ewe was assigned a locomotion score using the five-point system of Ley et al. (1994) (1: normal gait, 2: no obvious lameness when standing, occasional limping when walking, 3: lifting foot while standing and moderate lameness when walking, 4: shifting stance and severe lameness when walking, 5: unwilling to bear weight on one foot when standing or walking). Ewes with score ≥2 were marked and were subsequently subjected to a detailed clinical examination. Ewes with clinical evidence of other pathological conditions were excluded from the study. A detailed and comparative examination of legs and hoofs was carried out and the diagnosis of causes of lameness was performed as described by Winter (2004).

Data management and analysis

In total, complete history data (parity number, age at previous lambing, date of previous lambing) were available for 1,119 ewes, which were included in the below described models.

A binary logistic regression model (model 1) was developed in order to assess impact of lambing season (2 levels, 1: early lambing, October to December, 2: late lambing, January to March), pasture use (2 levels, 1: grazing, 2: zero grazing), stocking density (2 levels, 1: <2 m²/ewe, 2: ≥2 m²/ewe), parity number (4 levels, 1: 1st, 2: 2nd, 3: 3rd, 4: >3rd parity - adjusted for age at lambing) and flock size (continuous variable) on lameness occurrence.

An ordinal logistic regression model (model 2) was built to evaluate the effects of lambing season (2 levels, 1: early lambing, October to December, 2: late lambing, January to March), pasture use (2 levels, 1: grazing, 2: zero grazing), stocking density (2 levels, 1: <2 m²/ewe, 2: ≥2 m²/ewe), parity number (2 levels, 1: 1st or 2nd parity, 2: >2nd parity - adjusted for age at lambing) and flock size (continuous variable) on locomotion score. Three levels of locomotion score were used (0: locomotion score 1, 1: locomotion score 2 or 3, 2: locomotion score 4 or 5); the locomotion score assigned on the initial examination of the animal was taken into account and subsequent changes (increase or decrease of score, coinciding with deterioration or improvement of the condition) were not considered.

In Model 1, the Omnibus test was used, in order to test the predicting value of the model versus a model including only the intercept. Goodness of fit was tested using Hosmer and Lemeshow test providing information concerning adequacy of data fitted into the model. Model fitting information and goodness of fit was also calculated for Model 2. Parity number was set at 2 levels, to improve goodness of fit of Model 2. Moreover and in order to test the assumption that regression coefficients were the same across the different categories of the depended variable (locomotion score), test of parallelism was used.

Statistical significance was set at $P < 0.05$. All statistical analyses were performed using PASW© Statistics 18 (SPSS Inc., Chicago, IL).

RESULTS

Mean incidence risk of lameness in the nine flocks during the studied lactation period was 6.8% (110 cases in 1618 examined ewes). Between flocks range
of the incidence risk was 0.4%-22.0%. Most cases of lameness (69%) were first recorded during the first four months after lambing; mean interval from lambing to first occurrence of lameness of 108±44.5 days. Lameness incidence was higher during the period February to April (52% of all cases recorded) and smaller during July (2% of all ewes were affected).

Lameness was diagnosed more often in the hind legs (60% of ewes with the disease) than in the front legs (40% of ewes). More often, it involved only one claw of the affected foot (75% of cases; in 63% of these cases inner claw affected, in 37% of these cases outer claw affected), rather than both claws of the same foot (25% of cases). More specifically, localisation of lesions causing lameness was as below: rear leg/inner claw 28% of all ewes affected, rear leg/outer claw 17% of all ewes affected, rear leg/both claws 15%, front leg/inner claw 19%, front leg/outer claw 11%, front leg/both claws 10%.

With regard to severity of the condition, in 48% of lame ewes lameness was found to be severe (locomotion score 4 or 5). In 42% of ewes it was considered to be mild (locomotion score 2 or 3) and in 10% of ewes it was considered to be slight (locomotion score 1).

Of the various lameness causes, foot-rot was the main one and accounted for 66% of all cases of the pathological condition. White-line abscesses, white-line disease, pedal joint abscesses and injuries were also diagnosed (16%, 12%, 3% and 3% of all ewes affected, respectively). Information regarding incidence risk of the various lameness causing diseases is presented in Table 1.

In model 1, the Omnibus test was significant: \( \chi^2 = 85.02 \) (7 degrees of freedom; \( P < 0.001 \)), predicting better the outcome variable in comparison to the model including intercept only; goodness of fit was adequate (\( P = 0.506 \)). Effects of different categorical variables on the odds of lameness are shown in Table 2. Stocking density, flock size, lambing season and parity number were found to be significantly associated with the occurrence of lameness. Ewes housed in a space of <2 m\(^2\) per ewe were at 2.31 times higher odds of developing lameness than ewes kept in a space of ≥2 m\(^2\) (\( P = 0.005 \)). Nevertheless, grazing was not found to have a statistically significant effect on development of lameness (\( P = 0.127 \)). Effect of flock size was also significant (\( P = 0.014 \)). Additionally, ewes that lambed during the period from January to March were at 1.59 times higher odds to develop lameness than ewes lambing during the period from October to December (\( P = 0.044 \)). The effect of parity number was also statistically significant (\( P < 0.001 \)). When comparisons were made with 1st parity ewes (reference category), 2nd parity ewes were 18.87 times more likely to develop lameness; ewes in their 3rd parity were 6.44 times more likely to develop lameness and 4th parity ewes were 6.77 times more likely to develop lameness.

Model fitting information produced a significant result for model 2, indicating that the model actually improved the prediction ability comparing to a model with intercept only: \( \chi^2 = 26.207 \) (5 degrees of freedom; \( P < 0.001 \)). Additionally, a non-significant result was produced when goodness of fit was used (both for Pearson, \( P = 0.116 \), and deviance, \( P = 0.368 \)), suggesting that the data fitted the model well, whereas the test of parallelism: \( \chi^2 = 6.966 \) (5 degrees of freedom) was not significant (\( P = 0.223 \)) and, hence, the assumption of parallelism was accepted. Effects of different categorical variables on severity of lameness

### Table 1. Causes of lameness in intensive and semi-intensive Chios-breed dairy sheep flocks in Greece.

<table>
<thead>
<tr>
<th>Cause of lameness</th>
<th>Number of cases diagnosed</th>
<th>Incidence risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot rot</td>
<td>73</td>
<td>4.5%</td>
</tr>
<tr>
<td>White-line abscesses</td>
<td>18</td>
<td>1.1%</td>
</tr>
<tr>
<td>White-line disease</td>
<td>13</td>
<td>0.8%</td>
</tr>
<tr>
<td>Pedal joint abscesses</td>
<td>3</td>
<td>0.2%</td>
</tr>
<tr>
<td>Injuries</td>
<td>3</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>110</strong></td>
<td><strong>6.8%</strong></td>
</tr>
</tbody>
</table>
### Table 2. Effects of different variables on development of lameness, as assessed by using a multivariable logistic regression model for data analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>No</th>
<th>Adjusted lameness incidence risk</th>
<th>Odds ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity</td>
<td>1st</td>
<td>253</td>
<td>1.19</td>
<td>[Ref.]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>390</td>
<td>18.46</td>
<td>18.87</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>3rd</td>
<td>223</td>
<td>7.17</td>
<td>6.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>253</td>
<td>7.51</td>
<td>6.77</td>
<td></td>
</tr>
<tr>
<td>Lambing season</td>
<td>Early lambing (Oct.-Dec.)</td>
<td>694</td>
<td>8.21</td>
<td>[Ref.]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late lambing (Jan.-Mar.)</td>
<td>425</td>
<td>12.47</td>
<td>1.59</td>
<td>0.044</td>
</tr>
<tr>
<td>Pasture use</td>
<td>Yes</td>
<td>356</td>
<td>7.02</td>
<td>[Ref.]</td>
<td>0.127</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>763</td>
<td>11.14</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>Stocking density</td>
<td>&lt;2m² per ewe</td>
<td>526</td>
<td>6.40</td>
<td>[Ref.]</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>≥2m² per ewe</td>
<td>593</td>
<td>13.69</td>
<td>2.31</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3. Effects of different variables on severity of lameness, as assessed by using a multivariable logistic regression model for data analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Odds ratio</th>
<th>Adjusted probabilities</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity</td>
<td>1st and 2nd</td>
<td>[Ref.]</td>
<td>88.8</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>3rd and 4th</td>
<td>0.96</td>
<td>92.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Lambing season</td>
<td>Early lambing (Oct.-Dec.)</td>
<td>0.75</td>
<td>91.7</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>Late lambing (Jan.-Mar.)</td>
<td>[Ref.]</td>
<td>87.6</td>
<td>6.9</td>
</tr>
<tr>
<td>Pasture use</td>
<td>Yes</td>
<td>1.86</td>
<td>88.9</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>[Ref.]</td>
<td>92.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Stocking density</td>
<td>&lt;2m² per ewe</td>
<td>3.37</td>
<td>86.2</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>≥2m² per ewe</td>
<td>[Ref.]</td>
<td>93.7</td>
<td>3.6</td>
</tr>
</tbody>
</table>

*LS 1: locomotion score 1, LS 2: locomotion score 2 or 3, LS 3: locomotion score 4 or 5.*
are presented in \(3\). The only variable in this model with a significant \((P < 0.001)\) effect on lameness severity was stocking density; when available space per ewe inside the sheep shed was \(< 2 \text{ m}^2\), an increase in lameness severity by one category was 3.37 times more likely than when the available space per ewe was \(> 2 \text{ m}^2\).

**DISCUSSION**

To the best of our knowledge, this is the first large scale epidemiological study of lameness in dairy sheep. Lameness incidence risk was found to be 6.8%. Information obtained during previous studies that we had performed, have suggested that farmers, despite considering lameness a significant issue in their flocks, underestimated its incidence (Gelasakis et al., 2008). Similar findings have been reported in meat sheep in Great Britain (Clements et al., 2002; Lewis, 2006). Given the negative impact of lameness on dairy sheep milk production (Gelasakis et al., 2010a), lameness incidence risk reported here suggest that, in dairy sheep, the problem is significant and needs to be addressed. However, it seems that it is not as important as for the modern dairy cow industry (Espejo et al., 2006; Espejo and Endres, 2007); for example, Cook (2003) and Bicalho et al. (2009) have reported lameness prevalence in dairy cattle of 24% and 48%, respectively. In any case, extrapolation of dairy cow results to sheep is often inappropriate and a series of explanations could account for the lower incidence in dairy sheep. These include the lower body weight of that species, the possible differences between the two species regarding the biomechanics of the claw and the differences in management (e.g., extensive use of concrete flooring in dairy cows).

High stocking density was identified as a potential risk factor for increased development and severity of lameness. In Southern European countries, during winter, sheep are kept indoors and have restricted access to paddocks. Decreased availability of space (<2 \text{ m}^2) in the shed coupled with inadequate ventilation and inadequate bedding material (Gelasakis et al., 2010b) can lead to increased humidity in the shed. Furthermore, the combination of low ambient temperatures (<15 °C) and high relative humidity (>70 %) can be associated with decreased water evaporation from straw bedding. That, coupled with manure accumulation, contamination of bedding and insufficient disinfection inside the barn during winter months would result in compromised hygiene, which favours proliferation and transmission of pathogens, such as *Dichelobacter nodosus* and *Fusobacterium necrophorum*. Such conditions are considered to be prime risk factor for development of foot-rot (Abbott and Lewis, 2005; Green and George, 2008; Sargison, 2008) and provide an explanation regarding seasonality of the increased risk for lameness development during winter months, which has been previously reported by other researchers (Graham and Egerton, 1968; Eze, 2002).

Increased flock size was associated, in the present study, with decreased lameness development. This might be a result of more effective management applied in large, more-commercially oriented, flocks. Kaler and Green (2008) found no association between flock size and lameness incidence in meat sheep in the United Kingdom. However, direct comparisons with the results of our study are difficult, due to the differences in production systems (meat sheep *versus* dairy sheep) and the socio-economic structure of the farming industry (United Kingdom *versus* Greece).

Chios-breed ewes have the highest milk yield during the 2nd lactation period (Gelasakis et al., 2010a), which could partially explain the increased risk of lameness for those animals. That may be associated with increased metabolic requirements of ewes during that period. Considering the plethora of research data from dairy cows, it becomes evident that incidence risk of lameness in dairy cow herds increases, following closely the patterns of increased milk yield, intensification of husbandry practices and genetic improvement. In our view, a broad interpretation of the underlying mechanisms of lameness in sheep is needed. Hence, lameness should be considered as one of the consequences of metabolic problems related to management mistakes, deficiency or excess of nutrients, in particular of micronutrients involved in enzyme and hormone systems. Increased milk production is associated with increased metabolic demands, which if not met, would lead to failure of body organs or tissues. The prevailing view is that foot-rot, the commonest specific disease causing lameness in sheep, can have various clinical presentations (from benign to extremely severe), depending on the strain of *D. nodosus* involved, the immunological status of the animals, the climate and the flock management (Wassink et al., 2004).

In the studied flocks, the strains of *D. nodosus* were not recognized; in general, there is no avail-
Foot-rot was found to be the main cause of lameness in Chios-breed dairy sheep in Greece. Mean incidence risk of lameness was found to be ~7%, indicating it as an important health problem in dairy sheep. Increased stocking density in the farm and parity of ewes have been identified as significant risk factors for the pathological condition.

CONCLUDING REMARKS

Foot-rot was found to be the main cause of lameness in Chios-breed dairy sheep in Greece. Mean incidence risk of lameness was found to be ~7%, indicating it as an important health problem in dairy sheep. Increased stocking density in the farm and parity of ewes have been identified as significant risk factors for the pathological condition.

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CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.