Farmers' practices and factors associated with the prevalence of all lameness and lameness attributed to interdigital dermatitis and footrot in sheep flocks in England in 2004

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Abstract

The aim of this study was to investigate whether the risk factors associated with all causes of lameness in sheep differed from those associated with the lesion specific causes of lameness, interdigital dermatitis (ID) and footrot (FR). A total of 809 randomly selected English sheep farmers participated in a postal survey in 2005. Data were requested on their management of lameness in 2004 and whether this had changed from 2003 and the prevalence of all lameness, and lameness caused by ID and FR. The farmer ability to recognise ID and FR was assessed from their responses to a written and pictorial description. On 443 farms where both ID and FR were correctly named by the farmer, the mean prevalence of all lameness, and lameness caused by ID and FR were 10.0% (95% CI: 8.9, 10.8), 6.5% (95% CI: 5.8, 7.3) and 3.1% (95% CI: 2.8, 3.6) respectively. The mean prevalence of all lameness on all 809 farms was not significantly different at 10.2% (95% CI: 9.2, 11.0). The data were analysed using negative binomial regression models with the three outcomes farmer estimated prevalence of all lameness and lameness caused by ID or FR in 2004. Farmers who changed management of sheep between 2003 and 2004 were excluded from the analysis, thus all fixed effects were the farmers' managements in 2003 and 2004 to ensure that the management was in place for at least one year before the prevalence estimates.

Routine foot trimming ≥once/year compared with no routine foot trimming was significantly associated with an increased prevalence of all lameness (prevalence ratio (PR)=1.34, p<0.01), ID (PR=1.50, p<0.01) and FR (PR=1.35, p=0.02). Footbathing was also significantly associated with increased prevalence of all lameness (PR=1.67, p<0.01), ID (PR=1.68 <0.01) and FR (PR=1.76, p<0.01). A stocking density of >8ewes/ha was associated with a significantly increased prevalence of all lameness

(PR=1.26, p=0.01) and ID (PR=1.39, p=0.01). There was a significantly lower prevalence of FR (PR= 0.73, p=0.02; PR= 0.70, p=0.05 respectively) on farms in the North East and South East of England. Separating lame sheep at pasture was associated with a decreased prevalence of all lameness and ID (PR= 0.75, p<0.01; PR=0.73, p<0.01) and location of the farm in South East England was associated with a lower prevalence of all lameness and ID (PR= 0.75, p=0.01; PR= 0.71, p=0.05 respectively). We conclude that management factors associated with all lameness, and lameness attributed to ID and FR are similar.

Keywords: sheep; lameness; footrot; interdigital dermatitis; risk factors; negative binomial regression

1. Introduction

Footrot (FR) and interdigital dermatitis (ID) are the two most common causes of lameness in sheep in the UK (Kaler and Green, 2008a), causing approximately 80% of lameness. Although clinically distinct, these two foot lesions are aetiologically linked and represent a continuum of foot damage from mild irritation of the interdigital skin to clinical interdigital dermatitis (ID) and then separation of the hoof horn (FR) as a damaged foot with no bacterial proliferation is invaded by ubiquitous *Fusobacterium necrophorum* followed by invasion with *Dichelobacter nodosus* (Egerton et al., 1969). The clinical distinction between ID and FR is not well correlated with the bacterial distinction with 60% of sheep with ID culture positive for *D. nodosus* (Moore et al., 2005).

Until 2002 whole flock control measures that were recommended to control footrot in sheep in the UK were routine foot trimming, routine footbathing, culling sheep repeatedly lame with FR, vaccination, use of clean pastures and well drained land, and selecting sheep that were resistant to FR (Morgan, 1987; Winter, 1989). Maintaining a closed flock where possible, or quarantining brought-in sheep before introduction to the main flock were also recommended (Winter, 1989). The recommended treatment for individual sheep affected with FR comprised trimming away the loose horn and underlying tissue and applying a topical foot spray, with long acting parenteral antibiotics reserved for severe cases of FR (Morgan, 1987; Winter, 1989). The recommended treatment for ID was footbathing sheep in 3% formalin or 10% zinc sulphate or using a topical foot spray (Winter, 1989).

In 2000, a study of 251 non - randomly selected sheep farmers in England and Wales was conducted by Wassink et al. (2003, 2004) to investigate farmers' management practices and their associations with the prevalence of FR and ID in their flock. In Wassink et al. (2003, 2004) questionnaire, farmers were asked to list the prevalence of FR and ID for each month of 2000. The highest monthly prevalence of FR and ID was then used in subsequent analyses. Factors associated with an increase in the prevalence of ID in ewes were 'sometimes/never' catching lame sheep compared with 'always', farm land 100m or less above sea level and renting–in winter grazing (Wassink et al., 2004). The factor associated with an increased prevalence of FR was routine foot trimming. The factors associated with a decrease in prevalence of FR were isolation of brought-in sheep; individual treatment of diseased sheep with parenteral antibiotic, foot trimming individual lame sheep and topical foot spray. There was no significant association between footbathing or vaccination and the prevalence of FR or ID in the flock (Wassink et al., 2003; 2004).

One limitation of the study carried out by Wassink et al. (2003, 2004) was that it used a non random sample of farmers, which affected the generalisability of the prevalence estimates. Two assumptions were that farmers could correctly recognise lame sheep and the causes of lameness and that there was a link between the managements in 2000 and disease in 2000. Consequently, when a study of randomly selected English sheep farmers (Kaler and Green, 2008a) was conducted to investigate farmer ability to recognise and name six common foot lesions of sheep the opportunity was taken to assess the managements associated with the prevalence of lameness on these farms. Approximately 83% and 85% of farmers correctly named ID and FR respectively (Kaler and Green, 2008a). There is also now evidence that farmers can identify lame sheep, at least from movie clips of sheep with a range of locomotion scores (Kaler and Green, 2008b) and can recognise, but not necessarily correctly name, common foot lesions (Kaler and Green, 2008a).

The objective of the current study was to investigate whether the risk factors associated with all causes of lameness in sheep differed from those associated with the lesion specific causes of lameness interdigital dermatitis and footrot in flocks where farmers correctly named both lesions with the aim of evaluating the patterns of risks for ID and FR and all causes of lameness

2. Materials and Methods

2.1. Data collection

The data came from a postal questionnaire which was sent out in 2005 to a random sample of 3000 English sheep farmers stratified by region of England (south west, south east, central, north west and north east) and flock size within each region. The sample size was calculated based on expected prevalence of 50% for any foot lesion with a precision of 2.5%, and 95% confidence intervals and adjusted for an expected response rate of 50% (Kaler and Green, 2008a). The questionnaire was pilot tested. Farmers were asked to estimate the prevalence of lameness in their flock in 2004 and the proportion of this lameness attributable to ID and FR. In addition, the questionnaire had a section with questions on management of lameness and general farm characteristics (Table 1; Table 2). Farmer recognition of ID and FR was validated by visiting 28 farms and the questionnaire repeatability was tested on the farm and by post. The results suggested that the methods were valid and repeatable (Kaler and Green 2008a).

2.2. Farms selected for analysis

Two datasets were generated for analysis. Dataset A (n= 809) included all farmers who replied to the questionnaire irrespective of their ability to name six common foot lesions of sheep (Kaler and Green, 2008a). Dataset B (n = 443) included only those farmers who correctly recognised and named both ID and FR. Seventy two farmers and 46 farmers from dataset A and dataset B respectively, who either changed their lameness management practices from 2003 to 2004 or did not answer this particular question, were excluded from the analyses so that management of lameness was in place at least 12 months before the estimates of lameness ID and FR and so were not temporally confounded. Dataset A was used to investigate risk factors associated with the overall prevalence of lameness and Dataset B was used to develop two models to investigate the risk factors associated with the prevalence of ID and FR.

2.3. Statistical analysis

Data entry and error checking were performed in Microsoft Access 2000 (Microsoft) and data were exported to Stata SE 9.0 (StataCorp, USA) for screening and analysis. The flock size was the average number of ewes ≥1-yr in the flock in 2004.

2.3.1. Model building strategies

Negative binomial regression modelling (Cameron and Trivedi, 1998) was used to estimate both univariable and multivariable associations between each outcome, i.e. the number of cases of lameness, ID or FR offset by the natural logarithm of flock size and explanatory variables. The likelihood ratio chi-squared test was used to test whether the over dispersion parameter was significantly different from zero to differentiate a negative binomial model from a Poisson model. A log link model with the variance as a function of the mean was used with a model structure as follows:

Number of cases on farm$_j$ in 2004 ~ α + offset + βX_j + e_j

where~ is a log link function, α is the intercept, offset is the natural log of flock size and βXj is a series of vectors of explanatory variables that vary by farm j, and e_j is the residual random error.

The linearity of continuous explanatory variables with the outcome was visually assessed using scatter plots and variables that failed this assumption were categorised. Farmers' responses of percent lame sheep they treated with individual treatments (Table 1) (i.e. foot trimming, antibiotic injections, antibiotic sprays, isolation, 'other') were categorised as: 0 = none, 1% -99% = some and 100% = all.

All explanatory variables with categories with less than 10 observations were either merged with other categories or excluded from the analysis. Pair wise correlations were also calculated for the explanatory variables. Breed was excluded from the analysis because there was no estimate of lameness by breed within farm and many farms had several breeds of sheep.

Crude associations between all explanatory variables and the outcomes were screened using univariable negative binomial regression. All variables associated with the outcome with $p<0.2$ were tested in the three multivariable models which were built using stepwise backward elimination (Dohoo et al., 2003). Explanatory variables with a category wise Wald test P value ≤ 0.05 or those variables which significantly improved the model with a likelihood chi squared test value of $p \leq 0.05$ were retained in the model. All the variables, regardless of their significance at the univariable level, were tested in the final multivariable models to check for residual confounding (Cox and Wermuth, 1996). In addition, explanatory variables that were significant in any of the three models were also retained in the other final models to aid comparison.

During model-building, confounding was assessed by observing the effect of addition or deletion of explanatory variables on the coefficients and outcome in the model. The predictor variables resulting in change of more than 25% in the model coefficients when added or removed were considered as confounders. All biologically plausible interactions were checked between variables in the final model.

For each of the three models, the model fit was evaluated by constructing the generalised linear models in Stata SE 9.0 (StataCorp, USA) with a log link and a family specification of negative binomial using the same value of the dispersion parameter, and same explanatory variables from the final negative binomial regression models. Deviance residuals and values of Cook's distance were examined to assess the overall model fit and assumptions, outliers and observations with undue influence on the models (Cameron and Trivedi, 1998).

3. Results

3.1. Selected farms

Of the 1313/3000 questionnaires returned, 809 were usable (Kaler and Green, 2008a). A total of 737 out of 809 farmers were included in Dataset A, these were farmers who did not change their management between 2003 and 2004 and might or might not have recognised FR and ID lesions correctly. There were 397 farmers that were included in Dataset B, these were farmers who correctly identified both FR and ID from the questionnaire (Kaler and Green, 2008a) and who had not changed their management of lameness from 2003 to 2004. There was a fair representation of farms from all five regions (Table 2).

3.2. General farm characteristics (all farms irrespective of recognition of lesions: Dataset A)

Approximately 65% (472/727) of the farmers had a flock size of ≤ 300 ewes (Table 2). The number of ewes less than one year of age ranged from 0 to 1200 with a median of 15. The median number of rams ≥ one year of age was 6 (inter-quartile range 3-13). Farmers reported very few rams less than one year of age in their flocks, with a median value of 0 (inter-quartile range 0-2). The median number of meat lambs sold and lambs still on the farm, but not finished (ready for slaughter) by the end of December 2004 were 279 and 20, respectively.

Mule was the most common ewe breed and was present on 60% (442/730) of farms. Approximately 50% of farmers reported the presence of 'other' breeds on their farm which included a variety of ewe breeds and breed crosses; the most common were Suffolk cross and Swaledale. The most common ram breeds were Suffolk and Texel respectively, on 407 (57%) and 364 (51%) farms out of 715. A total of 250 (35%) farms had 'other' breeds which included Swaledale, Lleyn, Beltex and Polled Dorset. Lameness management practices of the farmers are described in Table 2. The distributions of farmers' practices and flock structure were fairly similar for the farmers who did and did not correctly identify ID and FR (Table 2).

3.3. Prevalence of lameness, ID and FR

Ninety seven percent of 737 farmers reported that they had lame sheep in their flock in 2004. The overall mean prevalence of lameness per farm in 2004, irrespective of farmer lesion recognition (Dataset A), was 10.2% (95% CI: 9.2, 11.0) (Figure 1). On farms where both ID and FR were correctly identified, 96% (346/362) and 93% (318/341) of farmers reported the presence of ID and FR respectively. The mean prevalence of ID and FR (Dataset B) was 6.5% (95% CI: 5.8, 7.3) and 3.1% (95% CI: 2.8, 3.6) respectively (Figure 1) and the mean overall lameness was 10.0 (95% CI: 8.9, 10.8). On farms where both lesions were correctly identified 10 out of 339 farmers reported FR but no ID and similarly there were 23 farms where ID was present without FR. There was no obvious association between the prevalence of FR and ID within these farms in 2004 (Figure 2).

3.4. Negative binomial regression models for lameness, ID and FR

The univariate crude associations between explanatory variables and outcomes i.e. number of cases of lameness, ID, FR are presented in Table 2. The three multivariable models are presented in Table 3. Overall, the risks were similar for all three models, with significant estimates less frequent in the ID model and FR model, most probably because these models had a lower sample size.

The prevalence ratios (PR) for lameness, ID and FR where farmers routinely trimmed the feet of their flock once or more per year compared with those who did not routinely trim at all were 1.34 (95% CI: 1.15, 1.55) , 1.50 (95% CI: 1.18, 1.90) and 1.35 (95% CI: 1.03, 1.78) respectively. In all three models, the frequency of footbathing was significantly associated with the prevalence of lameness, ID and FR. Farmers who foot bathed their sheep once every 2 – 4 weeks had a significantly higher prevalence of lameness, ID and FR compared with those who did not footbath their sheep (PR: lameness = 1.67 (95% CI: 1.43, 1.95); ID =1.68 (95% CI: 1.30, 2.16); FR =1.76 (95% CI: 1.30, 2.37)) respectively. In addition, footbathing once every 3 - 12 months (PR= 1.26 (95% CI: 1.07, 1.48)) and 'when necessary' (PR= 1.47 (95% CI: 1.15, 1.88)) were significantly associated with a higher prevalence of all lameness compared with never footbathing and the trends were similar for ID and FR (Table 3).

Farmers who separated 'some' or 'all' of their lame sheep at pasture had lower PR for lameness and ID compared with those who separated none of their lame sheep of 0.75 (95% CI: 0.65, 0.87) and 0.73 (95% CI: 0.58, 0.92) respectively. Farmers who had a stocking density of >8 ewes/ha compared with farmers that had stocking density of ≤8 ewes/ha had a PR for lameness and ID of 1.26 (95% CI: 1.05, 1.50) and 1.39 (95% CI: 1.09, 1.82) respectively. There was no significant association between separation of lame sheep or stocking density and the prevalence of FR.

The south east of England had a significantly lower PR for lameness, ID and FR compared with central England of 0.75 (95% CI: 0.61, 0.93), 0.71 (95% CI: 0.52, 1.00) and 0.70 (95% CI: 0.48, 0.99) respectively. In addition, the north east of England also had a significantly low PR for FR compared with the central region of 0.73 (95% CI: 0.53, 0.93). There was no evidence for confounding or interaction between variables in the final models.

The probability plots of deviance residuals of the three models were approximately normal. None of the farms had undue influence on the models from the plot of Cook's distance against the predicted mean number of lameness / ID / FR cases. Removal of the outliers did not change the model results significantly. The likelihood ratio tests for all the three models for dispersion parameter =0 was p<0.01 suggesting that the variance was greater than would be expected for Poisson regression and that negative binomial models were more appropriate.

4. Discussion

The risk factors for both ID and FR were investigated separately to differentiate the possible risks for lameness caused by each lesion and to see whether management factors were associated with specific presentations of lameness. Although there was a difference in factors significantly associated with both these conditions (Table 3), the associations were in a similar direction for nearly all factors for ID and FR. The failure to detect a significant association between some variables that were significantly associated with ID and FR might have occurred because there was less power in the FR model because the prevalence of FR was lower. The factors significantly associated with the prevalence of lameness were, in fact, a combination of factors associated with prevalence of ID and FR; this reiterates the importance of ID and FR as the most common causes of lameness in sheep flocks. This is a useful result because we can target management of lameness and, if farmers know that they have FR and ID in their flock (and over 90% do) then we can test interventions that will reduce lameness.

Only farmers who did not change their management between 2003 and 2004 were included in the current analysis to avoid the risk that a high prevalence of lameness had caused a management practice. This was an improvement on Wassink et al. (2003, 2004) where the lameness management and lameness estimates were collected for the same year. Thus, the reported associations between certain management factors and lameness in previous studies could have been because high lameness led farmers to choose a management approach.

In the current study, there were only 10/339 farmers who reported the presence of FR without ID. This supports the close link between ID and FR both in terms of the aetiology and clinical picture (Egerton et al., 1969) and the current thinking that ID (or at least invasion with *F. necrophorum*) is necessary for the occurrence of FR or that ID is sometimes a mild presentation of FR (Moore et al., 2005). On these 10 farms it is possible that there may have been some non lame sheep with ID or that these farmers had mis-diagnosed FR, despite their apparent ability to recognise FR in the questionnaire.

Despite the close association between ID and FR there is a possibility that ID lesions may not develop into FR because of variability in either host susceptibility or farm management (Wassink et al., 2003) or rapid treatment of lame sheep. This may explain the low correlation between the prevalence of FR and ID on some farms (Figure 2), and the fact that there were 23/339 farms with ID without FR. In addition, whilst *F. necrophorum* is present on all farms, *D. nodosus* is an obligate anaerobe, surviving off host for a small amount of time (Beveridge, 1941). Consequently, it is possible that *D. nodosus* was not present on these 23 farms.

Several limitations should be considered when interpreting results from the current study. Although the farms in both Datasets A and B were similar in regional distribution and flock size ($p>0.05$), they differed significantly ($p <0.05$) from the DEFRA (Department of Environment, Food and Rural Affairs) agricultural census of 2004 with respect to flock size and geographical location (Kaler and Green, 2008a). Also, although there was no significant difference between respondents and non-respondents with respect to geographical location and flock size (Kaler and Green, 2008a), there is a possibility of non response bias in the overall response to the survey (e.g. it might be that farmers that had higher levels of lameness/ID/FR preferentially responded to the survey) and to specific questions, although the response rate to most questions was very high (>85%). Finally, all the questions were asked for the previous year, thus there is the possibility of recall bias.

The prevalence of lameness, ID and FR were significantly lower in eastern England. Wassink et al. (2003), also reported a lower prevalence of FR in the east of England, where there are warmer summers, colder winters and lower average rainfall compared with other parts of England (Anon., 2004). This adds to the evidence for the importance of warm, wet conditions for the transmission and expression of FR (Green and George, 2008), in addition to the inflammation of interdigital skin (Beveridge, 1941; Parsonson et al., 1967; Roberts and Egerton, 1969).

A high stocking density of > 8 ewes/ha and separating ‘some or all’ lame sheep at pasture / housing that were significantly associated with higher and lower prevalence of both lameness and ID respectively, and the trend was similar for FR. Wassink et al. (2003) reported a lower prevalence of FR in flocks where farmers separated sheep with FR and it is probable that ID will also be controlled by this management when *D. nodosus* is present, due to the clinical link between ID and FR (Moore et al., 2005). More speculatively, the low prevalence of ID associated with separating lame sheep might be due to overload of the pasture with *F. necrophorum* (also reinforced by the association between high stocking density and ID) and thus separating lame sheep reduces this accumulation of *F. necrophorum.*

In contrast to the results published by Wassink et al. (2003) and Green et al. (2007), none of the individual treatments for diseased sheep i.e. foot trimming, parental antibiotic injections and topical sprays were significantly associated with the prevalence of lameness, ID or FR. There may be several reasons for this lack of association. The prevalence estimates requested from farmers in the current study were an average for the whole year, whilst Wassink et al. (2003, 2004) requested estimates of ID and FR in each month of the year and used the highest monthly prevalence over the year in the analysis. The overall variation in the reported prevalence of ID and FR among farmers in the current study was much less than that reported by Wassink et al. (2003, 2004) which might be a limiting factor in the current study and the greater variability in Wassink et al. (2003, 2004) might have highlighted that individual treatments were reducing the peak of mini-epidemics of FR or ID. This would occur if treatments were prompt. Thus, it is not only 'always' using parenteral antibiotics and topical sprays that helps to reduce the prevalence and incidence of infectious lameness but also the 'timely' use of this approach (Green et al., 2007; Hawker, 2008). Unfortunately, we did not ask about frequency and time to treatment. In addition, the questions regarding individual treatments were asked in a different way in the two questionnaires. Wassink et al. (2003, 2004) asked farmers whether they 'always' 'sometimes' or 'never' used various individual treatments to treat their sheep with FR. In the current study, farmers were asked to give a percentage of their lame sheep that they treated with each of the individual treatments (Table 1). The aim of this question was to increase precision, but it might be that, although apparently more precise, ironically farmers were less able to answer the question precisely or might have interpreted the question differently.

In the current study, routine trimming was significantly associated with an increased prevalence of ID, FR and lameness. The results suggest that even routine trimming once per year is associated with an increased risk of lameness; this is different from Wassink et al. (2003) where a positive association between routine trimming more than once a year and FR was reported. A second new result from the current study is that farmers who footbathed their sheep more frequently reported a higher prevalence of lameness, ID and FR compared with farmers who did not footbath their sheep. Amory et al. (2006) also reported the association of footbathing with a high prevalence of lameness in dairy cattle. As with routine foot trimming, the association between a higher prevalence of lameness, ID and FR with more frequent footbathing might be a result of increased transmission of *D. nodosus* due to gathering of diseased and sound sheep, poor technique that increased susceptibility of sheep or increased duration of disease. Although Wassink et al. (2003, 2004) reported no significant association between ID, FR and footbathing, they reported that only farmers who rated their footbathing facilities as ‘excellent’ had a significantly lower prevalence of FR compared with those who never footbathed their sheep or rated their facilities less than excellent and, from the tables in the Wassink et al. (2003) paper, the intercept term for footbathing was higher than that where farmers were not footbathing (Wassink et al., 2003). The strength of evidence for the managements footbathing and routine foot trimming and an increased prevalence of lameness is growing but we still do not know if this is directly causal or an indirect effect; this need further testing in a more robust study such a prospective cohort or an intervention study.

5. Conclusions

Our study highlights that the management factors associated with an increased prevalence of ID, FR and all lameness are similar. It supports previous evidence that separating lame sheep and low stocking densities are associated with a lower prevalence of lameness, ID and FR and that routine trimming and footbathing are associated with a higher prevalence of lameness, ID and FR. All these results are in the correct temporal sequence, the management being in place for at least one year before the prevalence estimates were made. Prospective cohort and intervention studies would help elucidate whether these associations are directly causal.

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Conflict of interest statement

The authors declare no conflict of interests.

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Figure Legend:

Figure 1: Prevalence of a) lameness b) interdigital dermatitis c) footrot within flocks in 2004

a) Lameness b) Interdigital dermatitis c) Footrot

Figure 2**:** Scatter plot of prevalence of interdigital dermatitis and footrot within farms in 2004