A within farm clinical trial to compare two treatments (parenteral antibacterials and hoof trimming) for sheep lame with footrot

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Abstract

From observational studies, farmers who use parenteral antibacterials to promptly treat all sheep with footrot (FR) or interdigital dermatitis (ID) have a prevalence of lameness of <2% compared with a prevalence of 10% lameness reported by farmers who treat lame sheep bytrimming affected feet. We tested the hypothesis that prompt treatment of sheep lame with naturally developing FR or ID with parenteral and topical antibacterials reduces the prevalence and incidence of lameness with these conditions compared with less frequent treatment by trimming hoof horn and applying topical antibacterials. A further hypothesis was that reduction of ID and FR would improve productivity. A lowland sheep flock with 700 ewes was used to test these hypotheses in an 18-month within farm clinical trial with four groups of ewes: two intervention and two control. The duration and severity of lameness was used to categorise sheep into three weighted scores of lameness (WLS): never lame (WLS0), lame for a maximum of six days with locomotion score 2 (WLS1) and lame for more than six days or a higher locomotion score (WLS2). The intervention reduced the prevalence of lameness due to FR and ID in ewes and lambs and the incidence of lameness in ewes. The WLS was significantly lower in sheep in the intervention groups. Ewes with a higher WLS were subsequently significantly more likely to have a body condition score (BCS) <2.5 and have lame lambs. Significantly more ewes lambed and successfully reared more lambs that were ready for slaughter at a younger age in the intervention versus control groups. There was an increase in the gross margin of £630 / 100 ewes mated in the intervention group, including the cost of treatment of £150 / 100 ewes mated. We conclude that prompt parenteral and topical antibacterial treatment of sheep lame with ID and FR reduced the prevalence and incidence of these infectious conditions and led to improved health, welfare and productivity.

Keywords: sheep; footrot; clinical trial; parenteral antibiotics; foot trimming; welfare; productivity

1. Introduction

Lameness is one of the greatest concerns for poor welfare in sheep (Goddard et al., 2006; Fitzpatrick et al., 2006). It has been estimated to cost the UK industry £24 million / annum (Nieuwhof and Bishop, 2005). More than 90% of farmers in the UK report lameness in their sheep, with a farmer-estimated prevalence of 10% with more than 80% of lameness caused by footrot (FR) and interdigital dermatitis (ID) (Grogono-Thomas and Johnston, 1997; Kaler and Green, 2008a). In a study of 209 sheep farmers, those treating all sheep with FR with parenteral antibacterials and foot sprays reported a significantly lower peak prevalence of FR of 2% compared with the 9%reported by farmers who treated FR by paring the hoof horn and spraying disinfectant on to the foot (Wassink et al., 2003). In addition, farmers who reported prompt treatment of mildly lame sheep also reported a lower prevalence of lameness than those treating groups of lame sheep (Kaler and Green, 2008). Further evidence for the benefits of parenteral antibiotics comes from a prospective longitudinal study of 160 sheep on one farm where the treatment of sheep with FR and ID with parenteral and topical antibacterials was associated with a lower incidence of lameness in the subsequent 4 weeks (Green et al., 2007).

Dichelobacter nodosus is the necessary pathogen to cause FR (Beveridge, 1941) and is present in the majority of cases of both ID (inflammation of the interdigital skin) and FR (separation of hoof horn from the underlying tissue) (Moore et al., 2005). As a consequence, ID and FR are often a continuum of the same disease. The terms that are equivalent to ID and FR in Australia are benign and virulent FR (Depiazzi et al., 1991). *D. nodosus* is an anaerobic bacterium that has no known resistance to antibacterials. Parenteral antibacterial treatment of FR leads to recovery from lesions in over 90% of sheep (Sterk, 1960; Egerton et al., 1968; Grogono-Thomas et al., 1994) and in a recent factorial design study, over 90% of sheep with FR treated with long acting oxytetracycline recovered from lesions and lameness within 10 days whilst <30% sheep treated with foot trimming recovered in this time period (Kaler et al., 2010). This, together with the evidence above and biological reasoning, led to the hypothesis that prompt treatment of lame sheep with ID or FR with parenteral and topical antibacterials would reduce the prevalence (because of a reduced duration of lameness) and incidence (because a reduced infectious period would decrease the probability of transmission of *D. nodosus* between sheep) of lameness caused by these diseases compared with the traditional treatment of trimming hoof horn and applying a topical bactericide. Consequently, the health, welfare and productivity of the flock should increase. To test these hypotheses, a within flock clinical trial comparing these two treatments was set up on a convenience-selected farm in Oxfordshire with a commercial lowland spring-lambing flock of approximately 700, mainly North Country mule ewes. The objective was to compare prompt treatment of FR and ID with parenteral and topical antibacterial with a typical farmer's management of FR and ID (Wassink et al., 2003; 2004) which includes less frequent treatment of lame sheep with ID and FR by trimming hoof horn and applying a topical bactericide. The study lasted from March 2005 to December 2006.

2. Materials and Methods

2.1 Study design March to September 2005

A sample size calculation was used to estimate the number of ewes required per treatment to test a reduction in lameness of 50% assuming a prevalence of lameness of 10%, 80% power and 95% significance. A total of 147 ewes were required per treatment.

Ewes lambed from the second week of March 2005. Ewes and lambs were identified with both ear tags and flank markings. The age (dentition), body condition score (BCS) (MAFF, 1994) and conformation of feet of ewes were recorded. All foot lesions were also (www.footrotinsheep.org) recorded. Ewes with triplets were excluded from the trial. After the ewes lambed they were allocated by researchers to one of two fields with similar pasture type and stocking density using stratified random sampling on age, BCS, foot conformation and presence of existing footrot lesions. Once the first two matched fields were stocked, two further fields with similar pasture type were filled. Each group consisted of approximately 175 ewes and their lambs (Table 1). The matched groups were moved between fields simultaneously and to similar pasture types and stocking densities throughout the trial period. In May 2005, when the youngest lamb in each group was four weeks old, one group from each pasture type was selected to be an intervention treatment group by tossing a coin; the other became the matched control group, thus giving two intervention and two control groups. Six observers collected data on age, BCS, locomotion and foot lesions over the 18-month study. All observers were trained by GJW who attended one day of data collection each week to check that observers remained consistent in their scoring.

A locomotion scoring system (Kaler et al., 2008b) was used by these trained researchers to score the locomotion of all sheep in all four groups each day for 5 weeks and then each weekday until October 2005. The identity, locomotion score and the limb or limbs that were observed lame were recorded for every sheep that had a locomotion score ≥1 in each group.

Treatments

Intervention groups: In the intervention groups, sheep with a locomotion score ≥2 were caught for diagnosis and treatment within 1-3 days of becoming lame. Their feet were inspected and the type and severity of lameness recorded. Sheep with FR or ID were treated with parenteral antibacterials (Terramycin LA 200 mg/ml, Pfizer Ltd; 20mg per kg bodyweight for ewes; and Engemycin LA 200 mg/ml, Intervet/Schering-Plough Animal Health; 15mg per kg bodyweight for lambs) and an antibacterial spray (Terramycin Aerosol Spray, 150ml pack, 4g Oxytetracycline Hydrochloride 3.92% w/w, Pfizer Ltd.). Other foot lesions were treated using standard protocols (Winter, 2004). When a sheep in an intervention group had a locomotion score ≥2 ten days after treatment it was re-caught, re-examined and re-treated.

Control groups: Lame sheep in the control groups were treated by the farm shepherd who had managed the flock for over 10 years. He inspected each group of sheep as part of his usual routine and was blind to the locomotion scores. When he elected to treat a sheep he was assisted by the research team who recorded the foot affected and cause of lameness. If ID was present, the shepherd trimmed the hoof horn wall and sprayed the feet with the topical spray above. If FR was present the hoof horn over lesions was trimmed away and the exposed lesions were sprayed with the topical spray. Other foot lesions were treated using standard protocols (Winter, 2004).

2.2 Changes to the study design after September 2005

Lambs were weaned on 20/08/2005. One month after weaning, one intervention group was selected by tossing a coin (solid grey line, Figure 1) and swapped with its matched control group in a cross over design. As a result, approximately 25% of the sheep were always in an intervention and 25% always in a control group, with the other 50% crossing over. Some ewes

(Table 1) were culled from all four groups and replacement ewes were added to the groups to balance the number of sheep per group. Both replacement ewes and rams used for mating were examined and if necessary treated. These sheep were not put with their group until sound. From October 2005, the treatments above were carried out twice each week in the intervention group rather than every week-day. No lame sheep were treated during early pregnancy (between 24th of October 2005 and the 9th of January 2006) except when sheep were gathered on 8th and 18th November and 12th December. The intervention groups were combined to facilitate housing on the 10th of February 2006. The control groups were also combined. Ewes were housed in several large straw-bedded solid-floored pens until they lambed. Straw was added to the pens each day and was 30 – 40 cm deep. Ewes were moved to individual pens after they had lambed.

2.3 Study design from May to September 2006

Two intervention groups and two control groups were re-formed from the merged intervention group and merged control group, respectively (Table 2). No ewes were put out to pasture until sound. Treatments for lameness started when the youngest lamb in a group was four weeks old. The intervention and control groups were treated as for the first lamb production season (2005) with the exception that lambs with ID were treated with topical antibacterials but not parenteral antibacterials.

2.4 Monitoring health and production in the flock

Ewe age, BCS and foot conformation and foot lesions were scored again at weaning in 2005 and at lambing and weaning 2006. The number of lambs born alive and dead, and the sex, birth weight and adoption details of all lambs were recorded in 2005 and 2006. Ewe and lamb deaths and the date lambs left the farms as finished or store lambs were also recorded in 2005 and 2006.

2.5 Data storage and analysis

Data were entered into a database (Access 2003, Microsoft) and checked for errors before statistical analysis in Stata SE 10, (Statacorp) and MLwiN 2.0 (Rasbash et al., 1999). Ewe body condition was categorised into below recommended (<2.5) and at or above recommended (≥2.5), birth weights were categorised by a good vs less good birth weight of <5.5kg and ≥ 5.5 kg and ewe age at a median of <4 years and ≥ 4 years. Breed was categorised into mule and other cross-breeds. Parametric and non-parametric tests were used to investigate univariable associations as appropriate for the data distributions.

Ewes at pasture with lambs from May – August 2005 and May – September 2006 were analysed separately from weaned ewes were at pasture; September 2005 to housing in February 2006. Data during housing were not used in the analysis because deep litter straw restricted observation of the ewes' legs.

The groups compared were intervention and control groups in 2005 and 2006 and also the sub group of ewes that were always in an intervention group or always in a control group (n = 176). These ewes were dispersed within the two intervention and two control groups in 2006.

The mean prevalence and incidence of lameness were plotted to visualise the effects of the intervention and the cross-over design. The prevalence and incidence of lameness in matched groups were compared using t tests. The prevalence was calculated from the number of sheep with locomotion score 2 or above at an observation divided by the number of sheep in the group divided by the number of days that observations occurred in a period. The incidence was calculated in the same way except that the denominator was the group size minus the number of non-susceptible sheep (those lame within the last 10 days).

Sheep had up to four episodes of lameness in a time period. To test the hypothesis that duration and severity of lameness affected production an weighted lameness score (WLS) was calculated where d = duration of an episode of lameness, m = maximum locomotion score during the episode of lameness, Σ = summed for all episodes of lameness in a time period

$$WLS = \Sigma (d*m)$$

an episode of lameness started on the day the locomotion score was first observed ≥ 2 and ended on the day midway between the last observation of locomotion score ≥ 2 and next observation of locomotion score <2, unless a sheep was observed lame again within 10 days in which case this was part of the current episode.

The WLS was then categorised into WLS0, sheep that never had a locomotion score ≥ 2, WLS1, sheep with a weighted lameness score ≤ 12 (e.g. a sheep lame over 2 episodes, one with 3 days of locomotion score 2 and another with 2 days of locomotion score 3) and WLS2, sheep with a weighted lameness score >12. This three level categorical variable was used in an ordinal multilevel multinomial regression analysis (Goldstein, 2003) to investigate impact of treatment on duration and severity of lameness. A multilevel binomial logistic regression analysis was used to investigate factors associated with ewe body condition (<2.5 or ≥ 2.5). Cox proportional survival analysis with robust estimates of variance using the cluster-option in Stata (Williams, 2000) was used to investigate the age at finishing for lambs.

A cost-benefit analysis of the intervention treatment vs control treatment was done using production figures from sheep that were in the intervention or control groups for the whole 18-month trial period and other existing data.

3. Results

3.1 Prevalence and incidence of lameness in ewes and lambs

Descriptive statistics are presented in Tables 1 and 2. The four groups started with similar numbers of ewes by BCS, foot conformation, FR and ID. Although there were fewer treatments in the control groups (Tables 1 and 2) there were significantly more episodes of lameness with a maximum locomotion score >2 compared with the intervention groups in both ewes and lambs (Tables 3 and 4) over the trial period. Ewes and lambs in the intervention groups were lame for significantly fewer days for each episode of lameness: 4.3 (CI: 4.0 – 4.6) and 4.0 (CI: 3.6 – 4.3) compared with ewes and lambs in the control groups 7.9 (CI: 7.2 – 8.7) and 7.3 (CI: 6.4 – 8.2) respectively.

The prevalence and incidence of lameness in ewes in the intervention groups fell in the first 4 – 8 weeks each time the intervention was introduced in 2005 and in 2006 (Figure 1). The mean prevalence and incidence of lameness in ewes was significantly lower in intervention vs control groups the both production seasons (Tables 1 and 2). In 2005, the mean prevalence of lameness in lambs was significantly lower in the intervention groups compared with the control groups from week 8 onwards (Figure 2, Table 1) but there was no significant difference in the mean incidence of lameness.

Over the intervention period, 35 isolates of *D. nodosus* cultured from ewes treated with parenteral antibacterials at least twice were tested for antibacterial resistance to oxytetracycline using a modified MIC test. All isolates were sensitive to oxytetracycline (DEFRA, 2008).

3.2 Factors associated with lameness

The intervention treatment significantly reduced the number and / or severity of lameness events: ewes and lambs in the control groups were more likely to have a WLS2 than ewes and lambs in the intervention groups (Table 1). WLS2 was also more likely in ewes > 4 yrs old (Table 5) and in lambs which were single born, male or their mother was lame, especially if the ewe had had a WLS2 (Table 5). Ewes were less likely to become lame between September 2005 and housing in February 2006 if they had been in the intervention group in 2005. A ewe was significantly more likely to become lame in this period if she had been lame in the previous lamb production period (Table 1).

3.3 Factors associated with ewe body condition

At the start of the intervention there were 73% sheep in the intervention and 77% sheep in control groups with BCS ≥2.5 (P>0.05). There were significantly more ewes with a BCS ≥2.5 in the intervention groups at weaning 2005 (62%), 2006 (76%) and lambing 2006 (83%) compared with ewes on the control groups with 26%, 62% and 61% with BCS ≥2.5 respectively at these times (*P*<0.01). BCS ≥2.5 at weaning 2005 was associated with a previous WLS of 0 or 1 than WLS2, a BCS ≥2.5 at lambing 2005, rearing one lamb, less than 4 years of age and mule breed

(Table 7). Ewes with a BCS≥ 2.5 at lambing 2006 were more likely to have had a WLS 0 or 1 than WLS2 in 2005, a BCS ≥ 2.5 at weaning 2005 and produced a single lamb in 2006.

3.4 Cost-benefit analysis of the intervention

The cost of reducing the prevalence of lameness in the first six weeks of the study in 2005 was £45 and £278 per 100 ewes in the two intervention groups; the prevalence of lameness fell more rapidly in one intervention group than the other (Figure 1).

There were 167 ewes that were either in intervention or control groups for the whole project. From week 8 until the end of the project the mean prevalence and incidence of lameness in ewes that were always in intervention groups (solid black line, Figure 1) were significantly lower than in ewes that were always in control groups (dashed black line, Figure 1) (2.4 (95% CI: 1.7 – 3.1) vs. 5.6 (CI: 4.6 – 6.6) and 1.4 (CI: 1.0 – 1.8) vs. 2.5 (CI: 1.9 – 3.1), respectively). These ewes were used to estimate the impact of the intervention on productivity because they remained under the same treatment for two seasons.

There were fewer barren ewes and ewes that died among ewes always in the intervention group than always in the control group, resulting in more productive ewes per 100 ewes put to the ram and lower replacement costs (Table 9). There were 17 more lambs reared per 100 ewes put to the ram. In 2006, one year after the intervention was started, a significantly higher percentage of lambs born to ewes always in the intervention group were finished before weaning compared with lambs born to ewes in the control group; 18% versus 6%, respectively (Table 8).

The additional cost of the intervention was calculated as £150 per 100 ewes put to the ram (Table 4). The intervention improved the gross margin by £630 in 2006 (Table 9), more than 50% higher than the gross margin in the control group.

4. Discussion

4.1 Impact on prevalence and incidence of footrot and interdigital dermatitis

We have demonstrated that prompt treatment of individual lame sheep with parenteral and topical antibacterials given to those with FR or ID significantly reduced the prevalence and incidence of lameness in ewes compared with delayed treatment of individual lame ewes with FR/ID treated with foot trimming and topical antibacterials. This latter management is used by the majority of sheep farmers in the UK and elsewhere in the world and so was an ideal control to provide useful results to farmers and to compare with a new practice. It is clear from our results that prompt treatment of FR/ID with parenteral and topical antibacterials was not only beneficial to sheep health and welfare but also cost effective, in that the ewes in the intervention groups were in better body condition, produced more lambs and reared them more rapidly, presumably because of their better body condition.

The reduction in prevalence of lameness occurred in ewes and lambs on each occasion that the intervention was started (May 2005, September 2005, May 2006). The reduction in incidence of lameness suggests that the treatment reduced re-occurrence in the same sheep; this could suggest that transmission of *D. nodosus* was reduced or foot health was improved. This might explain why there was no reduction in incidence of FR or ID in lambs; very few lambs were treated more than once. Alternatively, it might have been lack of power in the study because few lambs were lame.

All ewes with ID (as well as those with FR) were treated with parenteral antibacterials because in Moore et al., (2005) ID lesions were infected with *D. nodosus, the* cause of footrot on 60% of occasions. Lambs with ID were treated with parenteral antibiotics in 2005 but not 2006 because the farm shepherd was concerned about meat withdrawal times.

4.2 Impact on productivity

The impact of footrot lesions on bodyweight, lamb growth rates and wool growth in untreated sheep has been reported previously (Stewart et al., 1984; Marshall et al., 1991; Nieuwhof et al., 2008). This is the first paper to report the impact of duration and severity of lameness on production in meat sheep. It is useful to know that treating sheep lame with FR or ID promptly will make them more productive. The reduction in severity and duration of lameness in intervention groups was statistically associated with a higher body condition score (BCS) and greater lamb production. This is probably because low BCS affects fertility and fecundity (Rhind and McNeilly, 1986; Forcada et al., 1992; Abecia et al., 2006). Low BC in ewes also leads to high mortality in lambs (Binns et al., 2002), probably because of low birth weights (Christley et al., 2003; Everett-Hincks and Dodds, 2008) and insufficient production of colostrum and milk (Mellor and Murray, 1985; O'Doherty et al., 1997).

Significantly more lambs were finished before weaning in the intervention groups than in the control groups. This is a very important component of the cost effectiveness of the treatment because one of the main factors determining profitability of lowland flocks is the percentage of lambs finished (MLC, 2001). This is because supplementary feed to lambs after weaning is expensive and so impacts on profits. This, together with the production benefits from the current intervention (Table 4), indicates that it was cost effective to put in the extra time (approximately two treatments per 100 ewes per week) and drug resources needed to treat individual lame sheep. Rapid treatment of lame sheep might also prevent hyperalgesia that is reported in chronically lame sheep (Fitzpatrick et al., 2006) and so ensure that energy is put into body condition, reproduction and milk production.

4.3 Concerns regarding the development of antibiotic resistance

In this trial there was no evidence that the parenteral treatments led to bacterial selection for resistance to oxytetracycline. This might be because although there were many treatments they were staggered over time with 1 – 8 treatments per group per week, so there was no selective pressure for development of resistance. Whilst the use of parenteral antibiotic to treat infectious lameness might not be considered the ideal, it is highly efficacious as a treatment and, as this trial has clearly shown, of considerable benefit to animal welfare and production. It is the best current treatments, the alternatives, trimming and spraying individuals and the whole flock methods of footbathing and footrot vaccination are less effective treatments and in many sheep flocks in the UK do not lead to acceptable levels of lameness control (Kaler and Green, 2009; Kaler et al., 2010; Schwartzkoff et al., 1993).

4.4 Study design

This within farm clinical trial testing two treatments was carried out on one lowland spring-lambing flock with a compliant farm management team. This approach enabled us to make detailed observations and collect a comprehensive, reliable dataset. We are uncertain whether the improvements that occurred through the intervention would be quantitatively similar on other lowland sheep farms with similar management and prevalence of FR and ID in the UK and worldwide, but we would expect the qualitative results to be generalisable. The distribution of age, BCS, foot conformation (Hawker, 2007) and prevalence of lameness in ewes at the start of the study were similar in all four groups, suggesting that the random stratification was successful. The prevalence of lameness (8%) was also similar to that reported by farmers in previous studies (Grogono-Thomas and Johnson, 1997; Wassink et al., 2003; Kaler and Green, 2009). The group of ewes that moved from intervention to control came from the intervention group with the most rapid reduction in lameness in 2005 (grey solid bar Figure 1). The cross over in 2006 was used to demonstrate that lameness patterns followed the treatment regimes. The incidence and prevalence of lameness rose when sheep were moved from intervention to control groups and vice versa. This suggests that lameness was a correlate for control of FR and ID. The time to a stable prevalence of lameness of 1 – 2%, and the number of treatments required varied between intervention groups. This might have occurred because of differences in the environment in the fields within treatments or that some sheep in intervention group 2 were more infectious. Treatments were matched by field type to minimise the potential impact of climate and soil. Sheep were not in sufficient numbers of fields to test a treatment field interaction. Climate is important in clinical impact of *D. nodosus* (Green and George, 2008) and is one explanation for the difference in incidence of lameness between 2005 (a very wet, cool year) and 2006 (a hot, dry year). We used groups with the same treatments rather than individuals within groups because we wanted to test whether the treatment of lame sheep reduced transmission between sheep.

To minimise observer bias, all observers (n=6) were trained by GJW who also observed the observers once each week to prevent drift in scoring of sheep. In addition, observers regularly discussed scores to confirm continued agreement. A validated locomotion scoring system (Kaler and Green, 2008b) was used to assess the quantity and severity of lameness with paired groups inspected on the same day. The scales for scoring ID, FR lesions and foot integrity have not yet been evaluated and consequently might introduce error. Every effort was made to ensure that all sheep in each field were observed at each observation. Sheep were marked on their flank and had large ear tags. Despite this, sheep that were being observed after a lameness event were occasionally missed for one observation. There were no further feasible improvements that could be made to the design to reduce these reporting errors.

The farmer was blind to locomotion scores to prevent the possibility of him altering his usual management. He was an experienced stock person who had managed the flock for over 10 years and his treatment of FR is typical of that used by many farmers in GB (Wassink et al., 2003, 2004; Kaler and Green, 2008, 2009). This makes the results from this study highly relevant to many farmers and was the ideal baseline control for this clinical trial. It does mean that this study does not compare a treatment alone but time to known good treatment. There is a wealth of evidence that antibacterials lead to recovery from FR (Sterk, 1960; Egerton et al., 1968; Grogono-Thomas et al., 1994; kaler et al., 2010) and the aim of this study was more than repeating such research. Our results highlight that it is the duration and severity of lameness that affects sheep health and productivity and that is why we see an improved performance in sheep in the intervention groups. Rate of treatment is essential as well as appropriate treatment.

5. Conclusions

We conclude that prompt individual treatment of all lame sheep with ID and FR with parenteral and topical antibacterials reduced the prevalence of FR and ID in ewes and lambs and the incidence of these conditions in ewes. The reduced duration and severity of lameness improved the production of the flock through increased body condition in ewes which led to higher lambing rates, fewer deaths in ewes and lambs and earlier finishing of lambs. The cost-benefit was an increase in gross margin of £630 (€932) per 100 ewes put to the ram.

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Figure 1. Two-week mean prevalence and incidence of lameness in ewes between May 2005 and September 2006

Key: solid black line = always intervention, dashed black line = always control, solid grey line = intervention then intervention crossed over from control, dashed grey line = control then control crossed over from intervention

Figure 2. Two-week mean prevalence and incidence of lameness in lambs over two lamb production seasons, May – August 2005 and May – August 2006

Key: solid black line = dam always intervention, dashed black line = dam always control, solid grey line = dam intervention (2005) then intervention crossed over from control (2006), dashed grey line = dam control (2005) then control crossed over from intervention (2006)

Table 1. Descriptive statistics 2005

	Intervention Group 1	Intervention Group 2	Control Group 1	Control Group 2
	Control yr 2		Intervention yr 2	
No. ewes	175	177	181	177
No. lambs	364	323	357	312
Date first ewe lambed	7/03/2005	17/03/2005	11/03/2005	17/03/2005
% FR foot exam March 2005	26.1	20.5	19.4	20.9
% ID foot exam March 2005	44.9	43.8	38.9	50.3
No. treatments for FR & ID	78	232	20	18
No. treatments other lameness	5	4	2	0
Prevalence (95% CI) lame ewes	1.9 (1.1 – 2.6)	1.1 (0.6 – 1.7)	4.6 (2.6 – 6.7)	5.3 (3.5 – 7.1)
Incidence (95% CI) lame ewes	1.3 (0.7 – 1.8)	0.8 (0.4 – 1.2)	2.3 (1.4 – 3.1)	2.5 (2.0 – 3.0)
Prevalence (95% CI) lame lambs	0.8 (0.65 – 0.95)	1.41 (CI: 0.9 – 1.8)	2.5 (CI: 1.7 – 3.3)	1.45 (1.2 – 1.7)
Incidence (95% CI) lame lambs	0.4 (CI: 0.2 – 0.6)	1.1 (0.8 – 1.4)	1.1 (CI: 0.8 – 1.4)	0.6 (0.4 – 0.8)
No. (%) culled 2005	49 (28)	31 (18)	52 (29)	54 (36)
% FR foot exam Sept. 2005	5 (3)	10 (6.1)	22 (13)	18 (11)
% ID foot exam Sept. 2005	5 (3)	31 (19)	20 (12)	66 (39)

No. number, % percent

Table 2. **Descriptive statistics 2006**

	Intervention Group 3	Intervention group 4	Control Group 3	Control Group 4
No. ewes	147	147	144	132
No. lambs	265	278	267	240
Date first ewe lambed	13/03/2005	22/03/2006	12/03/2006	20/03/2006
No. (%)FR at exam March 2006	5 (3.4)	6 (4.1)	3 (2.0)	7 (5.3)
% ID at first exam March 2006	31 (21)	15 (10.2)	31 (21.5)	13 (9.8)
No. treatments FR&ID	102	76	23	49
No. treatments other lameness	8	2	5	1
Prevalence (95% CI) lame ewes	1.87 1.39 – 2.55	0.81 0.51 – 1.11	1.69 1.31 – 2.07	7.65 6.65 – 8.65
Incidence (95% CI) lame ewes	1.33 0.83-1.83	0.55 0.27 – 0.83	1.06 0.68 – 1.44	3.72 2.88 – 4.56
Prevalence (95% CI) lame lambs	1.55 1.09 – 2.01	0.46 0.22 – 0.70	1.03 0.75 – 1.35	4.29 3.59 – 4.99
Incidence (95% CI) lame lambs	1.01 0.59 – 1.43	0.21 0.07 – 0.35	0.72 0.12 – 1.32	1.84 0.44 – 2.24
No. (%) culled 2006	32 (22.0)	36 (24.4)	33 (22.9)	28 (21.2)
No. (%)FR foot exam Oct. 2006	0 (0)	0 (0)	7 (5)	20 (16)
No. (%) ID foot exam Oct. 2006	66 (44)	29 (20)	51 (38)	28 (22)

Table 3. Number of episodes of lameness by maximum locomotion score in ewes and lambs ; 2005 and 2006 data combined.

Maximum locomotion score[a]	Intervention ewe episodes (n=628)	Control ewe episodes (n=622)	Intervention lamb episodes (n=1047)	Control lamb episodes (n=1029)
2	271	257	306	262
3	45	85	43	94
4	46	85	56	89
5or 6	7	26	5	26

[a] Kaler et al., 2008b

Table 4. Number, percent, median and IQ range of weighted lameness score (WLS) for ewes and lambs in intervention and control groups; 2005 and 2006 data combined

	Intervention groups combined			Control groups combined		
	WLS 0	WLS 1	WLS 2	WLS 0	WLS 1	WLS 2
Ewes						
Number	398	143	86	390	95	136
percent	63	23	14	63	15	22
WLS Median	0	6	27	0	6	63
WLS IQ range	–	4 – 8	18 – 48	–	4 – 9	29 – 137
Lambs						
Number	754	217	76	755	142	132
percent	72	21	7	73	14	13
WLS Median	0	6	24	0	6	52
WLS IQ range	–	4 – 8	18 – 40	–	4 – 8	28 – 98

Table 5. Multilevel multinomial logistic regression models of factors associated with weighted lameness score (WLS) 1 and 2 versus 0 in lactating and dry / pregnant ewes

		WLS 1 (n=238)		WLS 2 (n=221)	
	No. (%) exposed	OR	95% CI	OR	95% CI
Lactating ewes (n = 1245)					
Intervention vs control	626 (50)	1.47	1.10 – 1.96	0.62	0.46 – 0.84
≥4 yrs vs <4 yrs age	652 (52)	1.17	0.88 – 1.55	1.37	1.02 – 1.84
Random effects		Var.	SE	Var.	SE
Variation between years		0.05	0.21	0.09	0.22
Covariance with score					
Ewe		-0.01	0.16		
Ewes dry / pregnant always intervention or control (n = 174)		WLS 1 (n=60)		WLS 2 (n=41)	
Intervention vs control	98 (56)	0.63	0.31 – 1.26	0.19	0.08 – 0.43
Ewe WLS>0 May - Sept 2005	79 (45)	1.98	1.00 – 3.93	4.01	1.80 – 8.96

No. number, % percent, OR: odds ratio, CI, confidence interval, Var.: variance, SE: standard error

Table 6. Multilevel multinomial logistic regression model of factors associated with higher weighted lameness score (WLS) in lambs in both 2005 and 2006

	No. (%) exposed	WLS1 (n=355)		WLS2 (n=207)	
Intervention vs control group	1033 (50)	1.54	1.21 – 1.96	0.62	0.45 – 0.84
Ewe WLS>0	754 (37)	2.49	1.96 – 3.16	3.54	2.60 – 4.80
Single vs twin	420 (20)	1.45	1.10 – 1.92	1.44	1.02 – 2.05
Male vs female	1058 (51)	1.28	1.01 – 1.63	1.73	1.28 – 2.36
Random effects		Var.	SE	Var.	SE
Variance within litters		0.24	0.18	0.44	0.27
Variance between litters		0.00	0.00	0.00	0.00
Covariance with score					
Litter		0.40	0.16		
Ewe		0.00	0.00		

No. number, % percent

Table 7. Multilevel multivariable binomial logistic regression model of factors associated with ewe body condition ≥ 2.5

At weaning 2005 and 2006				
Variable	No. (%) exposed	OR	95% CI	*P*-value
Ewe body condition at previous lambing ≥2.5 vs <2.5	880 (77)	2.83	2.09 – 3.83	<0.01
Rearing single lamb vs twin	390 (34)	1.80	1.38 – 2.36	<0.01
WLS2 compared with WLS0 or WLS1 before weaning	218 (19)	0.54	0.39 – 0.75	<0.01
Ewe age <4 vs ≥4 yrs	543 (47)	1.59	1.23 – 2.05	<0.01
Mules vs other crossbreeds	814 (71)	1.52	1.14 – 2.02	<0.01
Random effects	Var.	SE		
Variation between years	0.13	0.16		
Lambing 2006 - Ewes always in the intervention or always in control groups (n=167)				
Ewe body condition at weaning 2005 ≥2.5 vs <2.5	90 (54)	7.63	3.30 – 17.65	<0.01
WLS2 between Sept 2005 and Feb 2006 compared with WLS0 or WLS1	39 (23)	0.31	0.13 – 0.73	<0.01
Single vs multiple litter	42 (25)	2.73	1.02 – 7.26	<0.05

WLS weighted lameness score, No. number, % percent, OR: odds ratio, CI confidence interval, Var.: variance, SE: standard error

Table 8. Performance and cost-benefit analysis of the intervention from weaning 2005[a] to weaning 2006 per 100 ewes put to the ram.

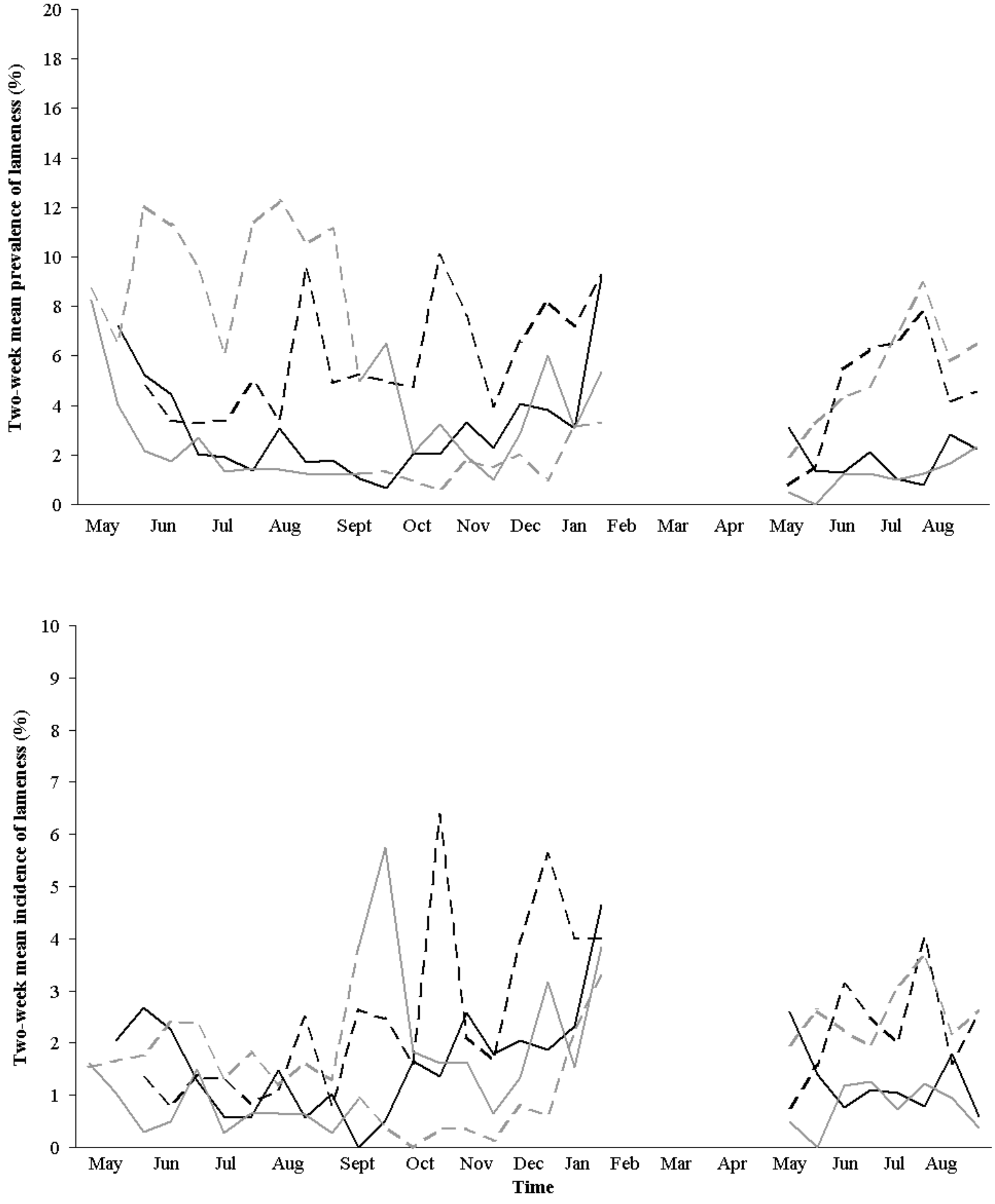
Performance	Intervention (No./100 ewes)	Control (No./100 ewes)	Financial results	Intervention (£)	Control (£)
Empty ewes	4	7	Slaughter lamb sales @ £35 / lamb	1098	331
Ewe deaths	3	5	Store lamb sales @£25 / lamb	3572	3701
Productive ewes	93	88	Wool	140	132
Total lambs born	186	176	Gross receipts	4809	4165
Lambs born dead	7	10	Replacement costs @£48.50 per ewe	811	1055
Lambs born alive	179	166	**Total output**	**3998**	**3109**
Lambs deaths after birth	5	9	Feed costs £13.50 / ewe	1201	1136
Lambs reared	174	157	Vet & medicine @£5 / ewe	465	440
Lambs finished	31	10	Intervention cost [a]	150	0
Lambs sold as stores	143	148	Other costs £3.80	356	337
			Total variable costs	**2173**	**1914**
			Gross Margin	**1825**	**1195**

[a] Cost of treatment parenteral antibacterial £1, antibacterial spray £0.30, Time 5.6 min (unpublished data, The University of Warwick); Minimum wage cost (per hour): £5.05

Table 9. Cox proportional survival model of time to finishing of lambs.

Among 182 lambs finished before 140 days of age	No. (%) exposed	Hazard ratio	95% CI [a]	Wald χ^2	χ^2 *P*-value
In intervention vs control group	162 (89)	2.91	1.92 – 4.42	14.91	<0.01
Birth weight ≥ 5.5 vs <5.5kg	121 (66)	1.75	1.24 – 2.47	27.78	<0.01
Single vs twin lamb	98 (54)	1.44	1.07 – 1.94	30.71	<0.01
Proportional-hazards assumption test based on Schoenfeld residuals		χ^2= 2.21	*P*>0.1		
Among 188 lambs finished between 140 and 163 days of age					
Dam body condition score at lambing ≥ 2.5 vs <2.5	145 (77)	1.69	1.28 – 2.24	11.56	<0.01
In intervention vs control group	128 (68)	1.48	1.06 – 2.06	16.79	<0.01
Birth weight ≥ 5.5 vs <5.5kg	111 (59)	1.41	1.07 – 1.84	22.06	<0.01
Proportional-hazards assumption test based on Schoenfeld residuals		χ^2= 6.24	*P*>0.1		

[a] Robust 95% confidence intervals, No. number, (%) percent


Two-week mean prevalence of lameness (%)
20
18
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14
12
10
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6
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May Jun Jul Aug Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
Two-week mean incidence of lameness (%)
10
9
8
7
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5
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2
1
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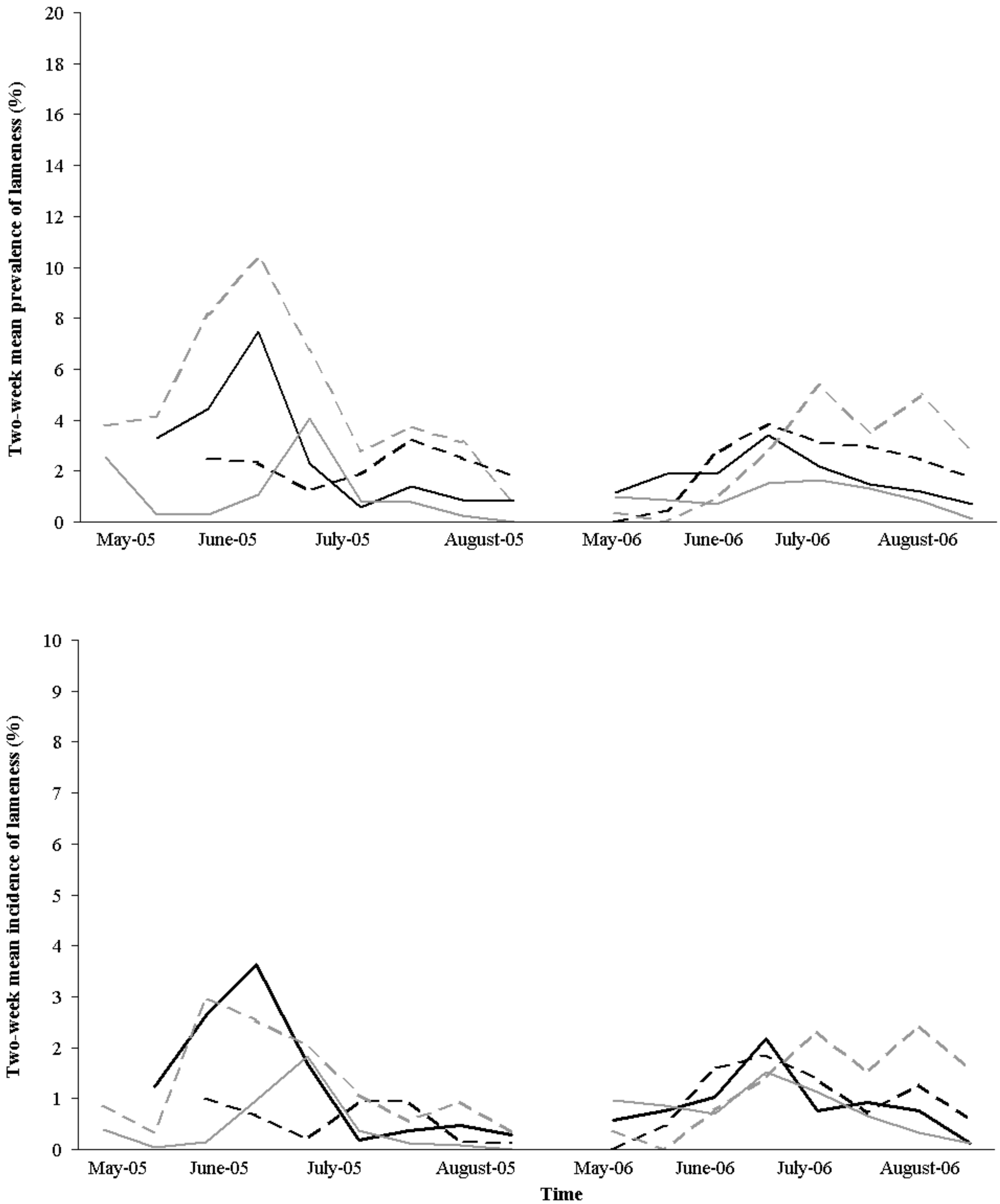
May Jun Jul Aug Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
Time

Figure 1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Two-week mean prevalence of lameness (%)
May-05
June-05
July-05
August-05
May-06
June-06
July-06
August-06
10
9
8
7
6
5
4
3
2
1
0
Two-week mean incidence of lameness (%)
May-05
June-05
July-05
August-05
May-06
June-06
July-06
August-06
Time

Figure 2