



Measuring the response to therapeutic foot trimming in dairy cows with fortnightly lameness scoring



M. Groenevelt ^{a,*}, D.C.J. Main ^a, D. Tisdall ^a, T.G. Knowles ^a, N.J. Bell ^b

^a School of Veterinary Science, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

^b The Royal Veterinary College, Stinsford Farmhouse, Kingston Maurward College, Dorchester, Dorset DT2 8PY, UK

ARTICLE INFO

Article history:
Accepted 11 May 2014

Keywords:
Dairy cattle
Lameness
Therapeutic foot trimming
Locomotion scoring

ABSTRACT

Lameness scoring (0–3) was carried out on four UK dairy farms during the housing period over three consecutive years (2010–2012). At the start of the study cows were matched by parity and stage of lactation and randomly allocated into a treatment (TX) and a control (CX) group. Cows were enrolled when two sound scores (0 or 1) were followed by a lame score (2). Farmers were immediately notified of score 3 cows, which were then excluded from the study, irrespective of whether they were in treatment or control groups. The animals in the TX group received treatment 3–48 h after being scored lame. Farmers remained blind to the treatment group. Throughout the study the participating farmers continued to identify and treat lame cows according to their usual approaches, this included treating animals in the CX or TX group if they so chose.

The fortnightly lameness scoring and treatment of the TX group resulted in higher cure rates at each scoring session following treatment when compared with the CX group ($P < 0.001$). Two weeks after inclusion, 78% (SE ± 3.2) of TX cows were sound, compared with 66% (SE ± 3.1) of CX cows. At 18 weeks following initial recruitment this had fallen to 41% (SE ± 6.3) (TX) and 13% (SE ± 4.7) (CX). The percentage of total scores which were sound scores in the TX and CX groups following inclusion in the trial was 81% and 66.1%, respectively ($P < 0.001$). The main lesions found on treatment in the TX group were sole haemorrhage (41% of cases) and digital dermatitis (33%). Severe lesions (sole ulcers and toe necrosis) were only found in 6.6% of cases. In the treated CX animals the percentage of severe lesions was 14%.

© 2014 Elsevier Ltd. All rights reserved.

Introduction

Lameness in dairy cows is detrimental to their welfare and productivity yet the level of lameness in dairy cows in the UK has remained high with a recent study reporting a mean prevalence of 37% with a range of 0–79% (Barker et al., 2010). Lameness is a painful condition (Whay et al., 1997) and has a negative impact on longevity (Booth et al., 2004), fertility (Huxley et al., 2007) and milk production (Leach et al., 2012). These negative impacts may occur before a cow is visibly lame; Reader et al. (2011) showed that milk yield drops 6 to 8 weeks before the animal is identified as lame by lameness scoring.

A long duration of lameness in dairy cattle has been inferred by some authors either due to a high ratio of lameness prevalence to incidence (Clarkson et al., 1996; Green et al., 2002; Whay, 2002) or because milk production losses occur over a period of months before and after treatment (Green et al., 2002; Reader et al., 2011).

Delays in detection and treatment of lame cows until more advanced stages of lameness have developed have been shown to be an important risk factor for severe lameness (Bell et al., 2009). Nevertheless, delays in treatment by UK dairy farmers have been estimated to be as long as 65 days (Leach et al., 2012). Another UK study found that 10% of farms had the same severely lame cows on four, consecutive monthly scoring sessions (Barker, 2007). To the authors' knowledge, there are no studies which definitively indicate whether such cows are chronically lame, repeatedly lame or are failing to respond to treatment.

It has been suggested that prompt treatment is one of the most effective measures in bringing down the prevalence of lameness on farms (Bell, 2006; Reader et al., 2011). Early detection and treatment reduce both duration and severity of a lameness case. However, neither early detection nor early treatment has been properly defined, nor has efficacy been established. Leach et al. (2012) showed that early detection (mild to moderate lameness, within 2 weeks) and treatment within 48 h resulted in reduced locomotion scores compared with a control group. They also showed that the lesions found in animals treated early were less severe than those found in animals treated at the farmers' discretion.

* Corresponding author. Tel.: +44 1934852650.
E-mail address: margit.groenevelt@bristol.ac.uk (M. Groenevelt).

Table 1
Summary of the features of each of the four recruited farms.

	Farm 1	Farm 2	Farm 3	Farm 4
Scoring period year 1	25 January–30 June 2010	12 January–16 June 2010	26 January–30 June 2010	11 January–16 June 2010
Scoring period year 2	18 October 2010–4 April 2011	19 October 2010–22 March 2011	20 October 2010–4 May 2011	21 October 2010–19 May 2011
Scoring period year 3	1 November 2011–30 April 2012	–	4 November 2011–4 May 2012	2 November 2011–1 May 2012
Number of cows in milk (mean)	160	165	230	125
Average 305 day yield	7845 kg year 1 8273 kg year 2 9112 kg year 3	8675 kg year 1 8183 kg year 2 –	4867 kg year 1 4550 kg year 2 5019 kg year 3	9887 kg year 1 9570 kg year 2 9298 kg year 3
Level lameness at start of each year	36% year 1 44% year 2 31% year 3	32% year 1 33% year 2 –	43% year 1 28% year 2 38% year 3	32% year 1 47% year 2 33% year 3
Number of animals in control group (CX)	Year 1 19 Year 2 19 Year 3 18 Total 56	Year 1 22 Year 2 25 – Total 47	Year 1 24 Year 2 34 Year 3 37 Total 95	Year 1 18 Year 2 22 Year 3 18 Total 58
Number of animals in treatment group (TX)	Year 1 10 Year 2 12 Year 3 25 Total 47	Year 1 11 Year 2 10 – Total 21	Year 1 17 Year 2 21 Year 3 20 Total 58	Year 1 12 Year 2 13 Year 3 20 Total 45
Normal lameness treatments	Farmer, vet, foot trimmer	Farmer, vet foot trimmer	Farmer, foot trimmer	Vet, foot trimmer
Cubicle bedding	Sand on mats	Deep sand bedding	Straw on mattresses	Sawdust on mats
Foot bathing regime	Twice daily	3 or 4 times a week	When high level of D.D. detected by farmer	3 or 4 times a week
Routine foot trimming regime	Foot trimmer every 8 weeks for dry off trims	Foot trimmer every 8 weeks for dry off trims	No routine trimming done	Foot trimmer every 6 weeks for dry off trims

Lameness scoring has been promoted as a means to reduce lameness prevalence.¹ This study attempted to quantify recovery rates for dairy cows identified as new cases of lameness using lameness scoring at fortnightly intervals compared with traditional methods of lameness detection in current use by dairy farmers.

Materials and methods

Four dairy farms were recruited from clients belonging to Langford Veterinary Services Farm Animal Practice, a clinical teaching practice of the University of Bristol. The farms were selected on the basis of their size, location and because they had been willing to participate in the study. Farmers were asked to continue their normal procedures for identifying and treating cows for lameness throughout the study. These treatments were given by farm staff, a foot trimmer, or (when the farmer requested it) by the farm's veterinarian (Table 1). The farmers were asked to keep records of the animals that received treatment for lameness, the type of treatment administered and, whenever possible, the cause of lameness. The study was carried out under the University of Bristol Investigation number UB/11/054.

At the start of the study all cows on the farm were matched by parity and stage of lactation and randomly allocated to treatment (TX) and control (CX) groups. This was done again at the start of year 2. At the start of year 3 existing control and treatment cows stayed the same and new animals including newly calved heifers were matched by parity and stage of lactation and then randomly allocated to the treatment and control groups.

Lameness scoring (LS) was carried out at milking at fortnightly intervals (range 9–21 days) during the sampling periods shown in Table 1. Sampling started when all animals were housed and continued until turnout. All lactating animals were scored. When cows were dried-off they were not scored until their next lactation. Cows with LS of 2 or 3 in the initial two scoring sessions were excluded in order for all eligible animals to be deemed sound. LS was carried out by a trained scorer using the DairyCo mobility score² (Table 2). The scoring was always carried out by the same person with the exception of four scoring sessions which were carried out by one of three other scorers who had received the same training as the main researcher (MG). Standardization of LS was carried out twice every sampling period with the use of a set of 20 videos which the main researcher (MG) scored every 3 months to ensure scoring consistency.

¹ See: DairyCo. Early detection and recognition of lameness: <http://www.dairyco.org.uk/technical-information/animal-health-welfare/lameness/husbandry-prevention/mobility-scoring/early-detection/> Accessed 25 April 2013.

² See: DairyCo. Mobility score instructions: <http://www.dairyco.org.uk/resources-library/technical-information/health-welfare/mobility-score-instructions/> Accessed 25 April 2013.

Table 2
Lameness score definitions after DairyCo,³ derived from Whay et al. (1997).

Definition	Score	Description
Good mobility	0	Walks with even weight bearing and rhythm on all four feet, with a flat back. Long, fluid strides possible.
Imperfect mobility	1	Steps uneven (rhythm or weight bearing) or strides shortened; affected limb or limbs not immediately identifiable.
Impaired mobility	2	Uneven weight bearing on a limb that is immediately identifiable and/or obviously shortened strides (usually with an arch to the centre of the back).
Severely impaired mobility	3	Unable to walk as fast as a brisk human pace (cannot keep up with the healthy herd) and signs of score 2.

Cows in the TX group became eligible for treatment if they had had at least two sound scores (0 or 1) followed by a score 2 on one or both of the hind limbs. Fore-limb lameness cases were excluded from the study. Farmers were immediately notified of score 3 cows in order for them to be given the appropriate treatment, they were then excluded irrespective of which treatment group they had been assigned to.

Farmers had been informed at the start of the study that they would not be notified of the LS of control animals but instructed that any lame animal should be treated as normal regardless of whether they believed them to be treatment or control cows. CX cows therefore underwent the farmers' normal lameness treatment protocol. Farmers were specifically asked to record all lameness treatments given to any cow on the farm, including cow ID, leg treated and diagnosis of the problem.

Animals in the TX group were foot trimmed within 3–48 h by a vet (MG) who had received training in foot trimming and held a qualification demonstrating competency (NPTC level 2). If treatment could not be given within 48 h these animals were excluded. The intervention for the TX group involved therapeutic foot trimming following the Dutch five step method (Toussaint Raven, 1985) on both hind limbs, regardless of whether the lameness was unilateral or bilateral. Cows in the treatment group were retreated if they did not improve by the next scoring session

³ See: DairyCo. Mobility score instructions: <http://www.dairyco.org.uk/resources-library/technical-information/health-welfare/mobility-score-instructions/> Accessed 25 April 2013.

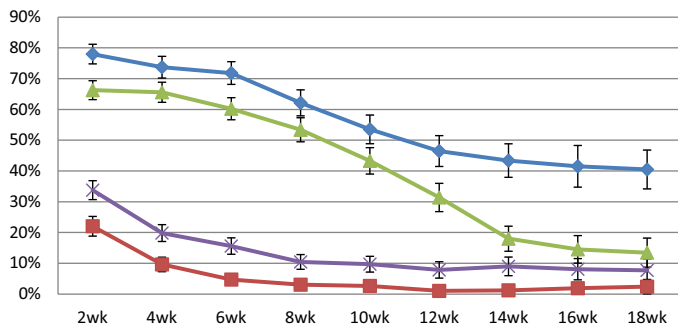


Fig. 1. Proportion of animals (± SE) that remained sound or lame over the 18 weeks following the initial lameness event for cattle treated within 48 h of elevated lameness score (TX) ($n = 168$ at week 2, $n = 42$ at 18 weeks) and for cattle treated at farmer's discretion (CX) ($n = 237$ at 2 weeks, $n = 52$ at 18 weeks). Blue line, TX stay sound; green line, CX stay sound; purple line, CX stay lame; red line TX, stay lame. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

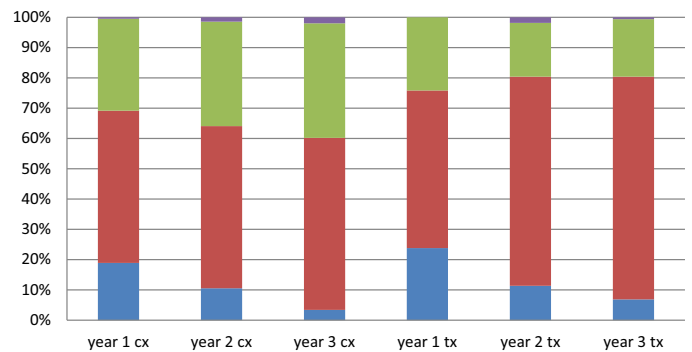


Fig. 2. Percentage of all scores over the three study years for the two treatment groups (TX and CX; see Fig. 1). Blue area, lameness score (LS) 0; red area, LS 1; green area, LS 2; purple area, LS 3. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

or if they relapsed during the sampling period. The primary lesions found were recorded using standard definitions (Archer et al., 2010a).

The data were entered into an Access 2003 database (Microsoft) and exported into an Excel 97–2003 spreadsheet (Microsoft) for descriptive analysis. To reliably examine cure rates, animals that missed one or more scores (for example due to drying off, sold, missed at scoring) were excluded after their last consecutive score. ‘Cure’ was defined as a LS <2 (i.e. score 0 or 1) and a non-cure or relapse was defined as a LS of ≥2 (i.e. score 2 or 3). The proportion of animals that had initially cured but then relapsed and stayed lame (RL) was calculated. By definition, a relapse could occur from 4 weeks after treatment (score 2, then 0 or 1, then 2 or 3).

In order to model the effect of treatment on lameness for each farm a binary logistic regression model was developed using the multilevel statistical software MLwiN (Rasbash et al., 2005). Using data for all 3 years, with lame or not lame as the outcome measure, a two level model (annual measurement within cow) was used with farm and visit number as fixed effects.

Results

Three of the four farms remained in the study for 3 years, with one farm withdrawing in the third year (Table 1). In total, 23,691 LS were taken from a total of 1195 cows. There were 171 animals selected and treated in the TX group and 256 animals in the CX group. Of these animals 42 and 53, respectively, had consecutive scores for 18 weeks (Fig. 1). The difference in numbers between the TX and CX groups was a result of periods of time when animals were scored but treatment could not be given within 48 h. This occurred occasionally when the foot trimmer (MG) was absent and during periods of farmer illness.

The proportion of animals that remained sound or lame after the initial lameness event decreased over 18 weeks in both the TX and CX group (Fig. 1). The proportion of animals that remained sound was consistently higher in the TX group than the CX group. The proportion of animals that remained lame was consistently higher in the CX group than in the TX group. From week 12 onward there was only one animal in the TX group that remained lame (LS >2). This

animal had been diagnosed with sole ulcers on the lateral claws of both hind feet at the first treatment.

Cows in the treatment group were less likely to be lame than those in the control group (odds ratio [OR] 0.44; 95% confidence interval [CI] 0.37–0.53; Table 3). This effect was consistent across the visits with no significant effect ($P = 0.109$) of the visit number on the proportion of cows being lame. Cows in farm 3 were significantly less likely to be lame than cows on farm 1 ($P < 0.001$).

When all scores gathered in the sampling periods were compared across years separately, between TX and CX groups, there was a highly significant difference ($P < 0.001$) between the proportion of scores for years 2 and 3 (Fig. 2). For year 1 this effect was not significant ($P < 0.121$). The percentage of lame scores (scores 2 and 3) was 19.0 and 33.9%, respectively ($P < 0.001$).

The main lesions found in the TX group at first treatment were sole haemorrhage and digital dermatitis (Fig. 3). There were 88 (51.5%) animals with only claw horn lesions, 22 (12.9%) with only soft tissue lesions, 56 (32.7%) with soft tissue and claw horn lesions, three (1.8%) with only upper leg problems, one (0.6%) with both upper leg and claw horn lesions and one (0.6%) with no lesions found. Severe lesions (sole ulcers and toe necrosis) were only found in 14 animals (8%). Heel horn erosion was considered to be the primary lesion causing lameness in only one animal.

Of the cows in the CX group only 10/256 (3.9%) had a recorded treatment by the farmer within 2 weeks of becoming eligible and so the majority of control cows appeared to achieve clinical cure without individual intervention (Table 4). However, as shown in Fig. 4, RL was more common in the CX group than the TX group. Overall a total of 19 CX animals had treatments recorded over the sampling period with a treatment delay of 37.7 days on average (range 7–126 days). Fourteen per cent of lesions were recorded as sole ulcers and 19% as interdigital necrobacillosis and 19% as digital dermatitis (Fig. 5).

Table 3

The effect of early intervention on subsequent lameness scores for cattle treated within 48 h of elevated lameness score (TX) compared with cattle treated at farmer's discretion (CX). The coefficients and their significance from the multilevel binary logistic regression model are shown together with the odds ratios associated with the various treatment effects.

	Co-efficient	S.E.	P value	Mean odds ratio	Lower 95% CI	Upper 95% CI
Constant (CX and Farm 1 – reference category)	–0.315	0.118	0.005			
Treatment (TX)	–0.811	0.092	$P < 0.001$	0.444	0.371	0.532
Farm 2	–0.194	0.145	0.179	0.824	0.620	1.094
Farm 3	–0.553	0.117	$P < 0.001$	0.575	0.457	0.723
Farm 4	–0.197	0.121	0.103	0.821	0.648	1.041
Visit number	0.003	0.016	0.109	1.003	0.972	1.035

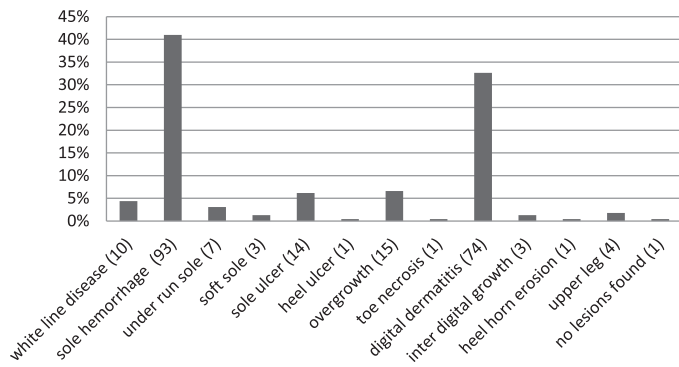


Fig. 3. Primary claw horn and soft tissue lesions found on treatment of cattle treated within 48 h of elevated lameness score ($n = 171$). Some animals had both primary soft tissue and claw horn lesions so the total number of lesions is 227.

Discussion

Lameness scoring has been promoted since 2001 as a means of screening herds for lameness (Zinpro, 2013) but, at least as far as the authors are aware, the work reported here is the first to attempt to evaluate the effectiveness of LS in combination with early treatment on farm to improve lameness cure rates in a longitudinal, randomized, controlled clinical trial.

One of the limitations of this study was that farmer detection and treatment of lameness acted as the control. It was clear that many of the lame control cows ($LS \geq 2$) were not treated during the study period and therefore there was a lack of data regarding the nature and severity of the lesions in these animals. Nonetheless, the study highlights the value of lameness scoring in ensuring cows that are likely to benefit from foot trimming, are actually treated. Furthermore, the results of this study shows there was significantly better cure rates and lower levels of chronically lame animals in the TX group compared with the CX group.

The TX group showed significantly lower lameness prevalence in years 2 and 3 of the study. In year 1 the prevalence of lameness was lower in the TX group but the result was not significant. There may be several explanations for this. Firstly the foot trimmer (MG) was less experienced and had not completed all her training in the first year of the intervention. Consequently, her trimming was also slower in the first year resulting in prolonged penning times after milking for the TX group only. Secondly, the sampling period in year 1 extended until the last herd had turned out to pasture, allowing many lame animals in the CX group to have had a period of recovery at pasture. In years 2 and 3 the sampling period was stopped for all farms when the first herd turned out.

The predominant lesions found in the treatment group were sole haemorrhage and digital dermatitis. Further work is needed to establish differences in cure rates for different lesions using this approach, but it is interesting to note that relatively mild disorders were found, with only 14 animals (8%) having more severe lesions such as sole ulcer and toe necrosis. According to this study, sole haemorrhage and digital dermatitis are probably much under-reported conditions causing early lameness. Although sole haemorrhage visible on the sole might not be directly relating to

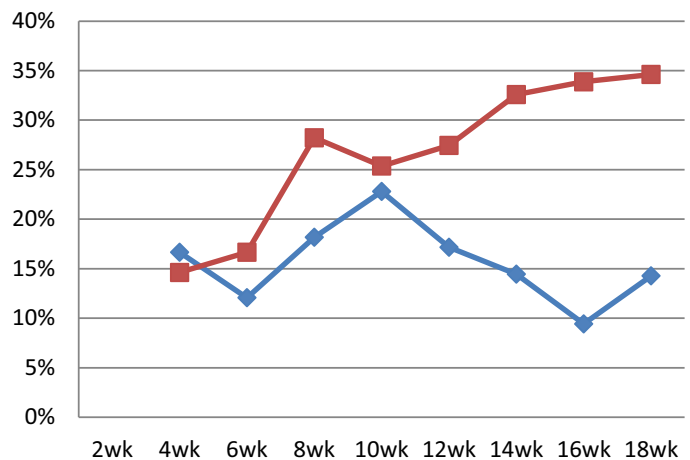


Fig. 4. The proportion of animals that after having cured initially (lameness score <2) now have a score of 2 or 3 for both treatment groups (TX and CX; see Fig. 1). Red line, CX relapse lame; blue line, TX relapse lame. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the state of the corium at that exact moment in time, it suggests that there has been trauma caused by or leading to an imbalance of weight distribution on that claw. None of the sole haemorrhages seen in this study disappeared during corrective foot trimming suggesting that the damage to the corium had extended over several weeks. The findings of this project suggest that sole haemorrhage caused by or leading to imbalance is a cause of early lameness in and of itself. Previously, the most common claw lesions identified in lame cows have usually been sole ulcers and white line disease (Murray et al., 1996; Barker, 2007). White line lesions were only found to be the primary lesion in 4% of the TX group (Fig. 3). Lesions that involve the corium in the white line area take time to establish and therefore the early detection and treatment used in this study might explain the low prevalence of this type of lesion.

None of the TX cows were diagnosed with interdigital necrobacillosis whereas 19% of the treated CX cows were diagnosed with this disease. It is likely that cases of necrobacillosis in both groups were identified and treated by the farmer without the researcher detecting these animals as lame; as treatment is usually straightforward with cows usually recovering quickly (Cook and Cutler, 1995).

The findings of this study also suggest that early intervention could be sufficient to prevent sole haemorrhage from progressing to more severe claw lesions. Of the 19 control animals that were treated within the scoring periods in the year that they had become eligible 14% showed sole ulcers compared with 6% sole ulcers found in the TX group. The average delay until treatment was 37.7 days, suggesting that some animals that only have sole haemorrhage when first detectable using lameness scoring will develop sole ulcers if treatment is delayed. This suggestion needs further research.

Similarly, cure rates for digital dermatitis could be improved by individual cow treatment in a crush compared with (formalin or copper sulphate) foot bathing alone (Stokes, 2011), particularly as others have demonstrated the difficulty in achieving bacterial cure

Table 4
Additional treatments given to cattle treated within 48 h of elevated lameness score (TX) and for cattle treated at farmer's discretion (CX). Treatment in TX group was always given by a researcher (MG); treatment in CX group was given by either the farmer or a vet.

	2 week	4 week	6 week	8 week	10 week	12 week	14 week	16 week	18 week
Additional treatment TX	15	33	12	12	8	11	1	3	0
Treatment CX	10	3	1	1	1	1	0	1	1

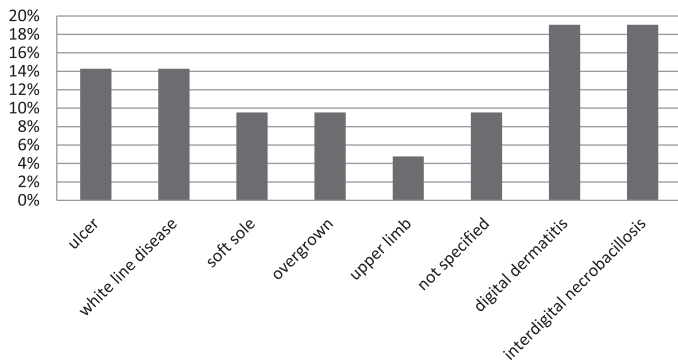


Fig. 5. Overview of lesions found on recorded treatments of cattle treated at farmer's discretion during the sampling period.

rate following initial treatment (Berry et al., 2010). Other treatment options for lame cows, for example access to a straw or similarly soft bedded yard, pain relief by injectable non-steroidal anti-inflammatory drugs or the application of a block in less severe cases have not been looked at during this study but could be effective too (Horseman et al., 2013).

A benefit of treating early lameness cases may be the reduced time required to treat them, although this has to be balanced by the fact that some cows with thin soles or those with upper limb problems which can account for 10% of lameness (Murray et al., 1996), may not benefit from foot trimming. The number of cows treated in the TX group far exceeded the number treated in the CX group (171 vs. 19). Some treatments in the CX group may not have been recorded as underreporting of treatments is common (Whay et al., 2003). However, the majority of TX cows only underwent functional trimming (Dutch five step method steps 1–3) with heel lowering on the painful claw (Dutch five step method step 4). Treatment of this nature is less difficult, will take less time and will be less painful for the cow. Blocks were only applied in 16 cases. Cases of digital dermatitis were treated by functional trimming of the foot, followed by superficial debriding of the lesions, drying of lesions and application of oxytetracycline spray (Engemycin; Pfizer Animal Health). Depending on the severity of the lesion, the farmer was told to continue spraying the foot twice a day for three consecutive days or until the lesion resolved.

Treatment of ulcers is often time consuming when done carefully and thoroughly. Even when taking care not to touch or damage the exposed corium, animals will demonstrate they are in pain, suggesting that even touching the area around the exposed corium is painful. Overall, treatment of severe lesions such as sole ulcers and toe necrosis is more labour intensive and costly than the treatment of just sole haemorrhage and claw imbalance. The time it takes to treat an individual lame cow is often mentioned (Horseman et al., 2014) as a limiting factor for farmers in the treatment of lame cows. The saved costs and benefits of treating these animals at an early stage however, are very likely to outweigh the time it takes to treat. Further work is necessary to explore this.

Early intervention using regular LS may improve milk production (Green et al., 2002; Archer et al., 2010b; Reader et al., 2011), fertility (Willshire, 2012) and cow longevity. On average, a lameness incident during lactation reduces the production of that lactation by 360 L (Green et al., 2002) although milk yield improvement may not be measurable in early cases (Leach et al., 2012). Furthermore, it should not be overlooked that lameness is a painful condition (Whay et al., 1997) and therefore treating lame animals promptly ensures a higher standard of animal welfare.

An interesting finding from this study was that many cows in the control group appeared to achieve clinical cure without recorded

individual treatment. Without lesion data for these animals the authors can only surmise that these cows had transient problems, and that cows were able to achieve cure through resting behaviour or that such cows responded to a herd treatment such as foot bathing. There is also a possibility that some individual cow treatments were not recorded by the farmer. Additionally, human error at scoring may play a role given the subjective nature of the LS and the practical challenges associated with lameness scoring as cows leave the parlour at speed. However, it is interesting to note that many of these animals relapsed several weeks later and that the relapse was more likely to result in a chronically lame animal (the 'get lame, stay lame' concept; Cook, 2007).

The high rate of relapse in the TX and CX group was an interesting and unexpected finding. One of the possible explanations for the relapse in the CX group could be the way the horn of the foot reacts to trauma and mediolateral claw imbalance. Claw asymmetry due to uneven horn wear (Telezhenko et al., 2009) is likely to be more extreme in lame cows; alternatively, traumatized and bruised claws may respond by producing more claw horn (Vokey et al., 2001). Initially this extra horn growth might protect the claw and lead to apparent recovery. Without therapeutic foot trimming, further trauma on the overloaded claw can prevent the animal from recovering from the contusion. However, when an animal is therapeutically foot trimmed the extra horn growth is removed to restore balance to the foot, breaking the cycle of overloading and trauma, which allows the corium to recover.

Relapses in the TX group could be due to the effect of the foot trimming alone not being sufficient for full corium recovery or that foot trimming itself may not have been the most efficacious treatment for some of these cows. Further work is needed to investigate treatment options for claw horn lesions including more proactive use of therapeutic blocks to raise a painful claw clear of walking surfaces. A further explanation for relapse in both TX and CX groups may involve animals with typical digital dermatitis lesions which fail to recover from a one-off application of oxytetracycline spray or the use of foot baths. Alternatively they may experience recurrence as they are genetically predisposed for conditions such as digital dermatitis (Scholey et al., 2010, 2012). Although a lot of research has been done on the treatment of digital dermatitis, there is still no unequivocal evidence for a best practice treatment (Stokes, 2011; Bell et al., 2013).

In this study LS was used to identify both lame animals and cure rates. Although LS is well accepted as a means of identifying lame cows, it does have disadvantages for on farm screening. It requires an extra (trained) person during milking to record the scores, which is time consuming and can be expensive when such a person needs to be hired, although the investment in labour is relatively small compared with other management tasks. To make sure consecutive scores are a reliable representation of the cows' mobility, it is important that the LS is always collected in the same way, in the same place and under the same conditions. There is always a risk that animals are missed, misidentified or wrongly scored. When the parlour exiting routine becomes disrupted, cows will often not show their normal behaviour and are more likely to conceal lameness. Bilateral hind limb lameness, which often occurs with sole haemorrhages, can be missed if the cow is distributing weight equally through each leg (Kujala et al., 2008). However, at present, it remains the best approach, with automated methods currently being less effective (Bicalho et al., 2007).

Although the difference between the TX and CX groups was significant for both the 2 week recovery rate and the average score following treatment, the differences were not as great as the authors had anticipated, prior to the study. The main benefit of early treatment may be delayed, often manifesting weeks after the initial treatment, when relapsed cases respond better to treatment. The

differences at first appear small but the cumulative effect over time is significant.

In our study the sampling periods only extended through the housing period. There were significant periods in the year when the TX group was managed using the traditional screening methods used by the farmers. Future research following this project could involve a more continuous intervention, and following cohorts of animals from first lactation, thereby removing the previous lameness events as a confounding factor.

A fortnightly interval of lameness scoring was used for practical reasons and reflected the practice of some farmers at the time of the study. This approach reduced lameness prevalence and prevented most, but not all, animals from developing lesions such as sole ulcers and toe necrosis that would normally have been progressing over several weeks. Further work is needed to establish if more frequent scoring could intercept these cases before they progress. While early detection and early, effective treatment can reduce lameness prevalence, cure rates fall substantially short of 100% and given the effort and skills required, it is no substitute for effective preventative measures.

Conclusions

Employing a 2-weekly scoring routine to detect and treat new cases of lameness in dairy cows resulted in higher recovery rates. Treated animals were less likely to relapse and had lower scores after treatment than a paired positive-control group. Early treatment of lame dairy cows resulted in the development of less severe lesions, increasing the chance of full recovery and decreased the amount of time an animal was lame. The findings of this study suggest that if regular scoring is carried out in combination with prompt and competent treatment, the prevalence of lameness will decrease where traditional methods of lameness detection are currently used on a farm.

Conflict of interest statement

None of the authors of this paper have a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

Acknowledgement

The authors would like to thank the generous funding of the Dartington Cattle Breeding Trust, the support of the participating farmers and the support of Tubney Charitable Trust. Preliminary results of year 1 were presented as an abstract at the 16th International Symposium and 8th Conference on Lameness in Ruminants, 28 February–3 March 2011, Rotorua, New Zealand.

References

- Archer, S.C., Bell, N.J., Huxley, J.N., 2010a. Lameness in UK dairy cows: A review of the current status. *In Practice* 32, 492–504.
- Archer, S.C., Green, M.J., Huxley, J.N., 2010b. Association between milk yield and serial locomotion score assessments in UK dairy cows. *Journal of Dairy Science* 93, 4045–4053.
- Barker, Z.E., 2007. Epidemiology of lameness in dairy cows. PhD Thesis, University of Warwick.
- Barker, Z.E., Leach, K.A., Whay, H.R., Bell, N.J., Main, D.C.J., 2010. Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. *Journal of Dairy Science* 93, 932–941.
- Bell, N.J., 2006. The alleviation and prevention of lameness in dairy heifers. PhD Thesis, University of Bristol.
- Bell, N.J., Knowles, T.G., Whay, H.R., Main, D.C.J., Webster, A.J.F., 2009. The development, implementation and testing of a lameness control programme based on HACCP principles and designed for heifers on dairy farms. *The Veterinary Journal* 180, 178–188.
- Bell, N.J., Blowey, R.W., Reader, J.D., Laven, R.A., Smith, R., 2013. Clinical forum: Digital dermatitis: Treatment and control. *Livestock* 18, 1–7.
- Berry, S.L., Read, D.H., Walker, R.L., Famula, T.R., 2010. Clinical, histologic, and bacteriologic findings in dairy cows with digital dermatitis (footwarts) one month after topical treatment with lincomycin hydrochloride or oxytetracycline hydrochloride. *Journal of the American Veterinary Medical Association* 237, 555–560.
- Bicalho, R.C., Cheong, S.H., Cramer, G., Guard, C.L., 2007. Association between a visual and an automated locomotion score in lactating Holstein cows. *Journal of Dairy Science* 90, 3294–3300.
- Booth, C.J., Warnick, L.D., Grohn, Y.T., Maizon, D.O., Guard, C.L., Janssen, D., 2004. Effect of lameness on culling in dairy cows. *Journal of Dairy Science* 87, 4115–4122.
- Clarkson, M.J., Downham, D.Y., Faull, W.B., Hughes, J.W., Manson, F.J., Merritt, J.B., Murray, R.D., Russell, W.B., Sutherst, J.E., Ward, W.R., 1996. Incidence and prevalence of lameness in dairy cattle. *Veterinary Record* 138, 563–567.
- Cook, N.B., 2007. The Dual Roles of Cow Comfort in the 'Get Lame – Stay Lame' Hypothesis, American Society of Agricultural and Biological Engineers, St. Joseph, MI.
- Cook, N.B., Cutler, K.L., 1995. Treatment and outcome of a severe form of foul-in-the-foot. *Veterinary Record* 136, 19–20.
- Green, L.E., Hedges, V.J., Schukken, Y.H., Blowey, R.W., Packington, A.J., 2002. The impact of clinical lameness on the milk yield of dairy cows. *Journal of Dairy Science* 85, 2250–2256.
- Horseman, S.V., Whay, H.R., Huxley, J.N., Bell, N.J., Mason, C.S., 2013. A survey of the on-farm treatment of sole ulcer and white line disease in dairy cattle. *The Veterinary Journal* 197, 461–467.
- Horseman, S.V., Roe, E.J., Huxley, J.N., Bell, N.J., Mason, C.S., Whay, H.R., 2014. The use of in-depth interviews to understand the process of treating lame dairy cows from the farmers' perspective. *Animal Welfare* 23, 157–165.
- Huxley, J.N., Main, D.C.J., Bell, N.J., Whay, H.R., 2007. Lameness and Infertility in UK Dairy Herds. Two Intractable Problems. Berlin, Germany.
- Kujala, M., Pastell, M., Soveri, T., 2008. Use of force sensors to detect and analyse lameness in dairy cows. *Veterinary Record* 162, 365–368.
- Leach, K.A., Tisdall, D.A., Bell, N.J., Main, D.C., Green, L.E., 2012. The effects of early treatment for hindlimb lameness in dairy cows on four commercial UK farms. *The Veterinary Journal* 193, 626–632.
- Murray, R.D., Downham, D.Y., Clarkson, M.J., Faull, W.B., Hughes, J.W., Manson, F.J., Merritt, J.B., Russell, W.B., Sutherst, J.E., Ward, W.R., 1996. Epidemiology of lameness in dairy cattle: Description and analysis of foot lesions. *Veterinary Record* 138, 586–591.
- Rasbash, J., Charlton, C., Browne, W.J., Healy, M., Cameron, B. 2005 MLwiN Version 2.02. Centre for Multilevel Modelling, University of Bristol.
- Reader, J.D., Green, M.J., Kaler, J., Mason, S.A., Green, L.E., 2011. Effect of mobility score on milk yield and activity in dairy cattle. *Journal of Dairy Science* 94, 5045–5052.
- Scholey, R.A., Ollier, W.E.R., Blowey, R.W., Murray, R.D., Carter, S.D., 2010. Determining host genetic susceptibility or resistance to bovine digital dermatitis in cattle. *Advances in Animal Biosciences* 1, 2.
- Scholey, R.A., Blowey, R.W., Murray, R.D., Smith, R.F., Cameron, J., Massey, J.P., Ollier, W.E., Carter, S.D., 2012. Investigating host genetic factors in bovine digital dermatitis. *Veterinary Record* 171, 624.
- Stokes, J.E., 2011. Investigating novel and existing methods of preventing, detecting and treating digital dermatitis in dairy cows. PhD thesis, University of Bristol, UK.
- Telezhenko, E., Bergsten, C., Magnusson, M., Nilsson, C., 2009. Effect of different flooring systems on claw conformation of dairy cows. *Journal of Dairy Science* 92, 2625–2633.
- Toussaint Raven, E., 1985. Cattle Footcare and Claw Trimming, Farming press Ltd, Suffolk, UK.
- Vokey, F.J., Guard, C.L., Erb, H.N., Galton, D.M., 2001. Effects of alley and stall surfaces on indices of claw and leg health in dairy cattle housed in a free-stall barn. *Journal of Dairy Science* 84, 2686–2699.
- Whay, H., 2002. Locomotion scoring and lameness detection in dairy cattle. *In Practice* 24, 444–449.
- Whay, H.R., Waterman, A.E., Webster, A.J.F., 1997. Associations between locomotion, claw lesions and nociceptive threshold in dairy heifers during the peri-partum period. *The Veterinary Journal* 154, 155–161.
- Whay, H.R., Main, D.C.J., Green, L.E., Webster, A.J.F., 2003. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records. *Veterinary Record* 153, 197–202.
- Willshire, J.A. 2012. The use of mobility score to predict dairy cow reproductive performance. Royal College of Veterinary Surgeons, London.
- Zinpro. 2013. The history of Zinpro Corporation [Online]. <http://www.zinpro.com/about-us/history> (accessed 25 April 2013).