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Uptake and effectiveness of interventions to reduce claw lesions in 40 dairy herds in the UK

ZE Barker[†], *JL Wright*[†], *RW Blowey*[‡], *JR Amory*[†§] *and LE Green*[*†]

[†] School of Life Sciences, University of Warwick CV4 7AL, UK
[‡] Wood Veterinary Group, Gloucester GL2 4NB, UK
[§] Centre for Equine and Animal science, Writtle College, Chelmsford, Essex CM1 3RR, UK
[*] Contact for correspondence and requests for reprints: laura.green@warwick.ac.uk

Abstract

In the final year of a three-year study of lameness in dairy cattle, 40 herds were allocated to either an intervention (22) or control (18) group. Farms in the intervention group were visited by a veterinarian who made up to 16 recommendations to reduce the incidence of lameness based on potential risks for lameness observed at that visit. Farms in the control group were visited and the same observations were made, but no changes recommended. All farms were visited on three further occasions to score the locomotion of all cows and collect information on changes made to the farm. Before intervention, the mean herd size, lactation average milk yield per cow and prevalence of severely lame cows were 122, 8,157 l and 9.85% for the control group and 109, 7,807 l and 9.14% for the intervention group. After the intervention there were no significant differences between the treatments in terms of the change in prevalence of severely lame cows or the change in rate of sole ulcer, white line disease or digital dermatitis. The overall uptake of recommendations was 41.3%. There were no significant correlations between the percentage of risks addressed and the rate of sole ulcer or prevalence of severely lame cows and only a non-significant trend for white line disease. Improvements to cubicle dimensions were associated with a reduction in the rate of sole ulcer, and changing nutrition and adding biotin to the ration were associated with a reduction in white line disease. Conversely, increasing the amount of sawdust to cubicle floors was associated with increased rate of sole ulcer and white line disease and improving cubicle dimensions was associated with increased rate of white line disease.

Keywords: *animal welfare, claw disease, dairy cattle, implementation, intervention study, lameness*

Introduction

Many risk factors have been associated with lameness in dairy cattle. These include factors related to poor cow comfort or reduced lying times (Barker *et al* 2007, 2010; Cook & Nordland 2009; Dippel *et al* 2009), poor quality walking surfaces in yards and passageways (Dembele *et al* 2006; Barker *et al* 2010), duration of time housed (Barker *et al* 2009), quality of tracks to pasture (Chesterton *et al* 1989; Barker *et al* 2009) and exposure to slurry or contaminated water in yards and passageways (Borderas *et al* 2004; Somers *et al* 2005; Gregory *et al* 2006). These studies provide statistical associations between lameness and management but do not provide strong evidence that the association is causal. One piece of strong evidence for causality is that when a risk is removed the incidence or prevalence of a disease decreases (Bradford Hill 1965). We do not know the impact of changing the above risks on the prevalence and incidence of lameness in dairy cattle.

There have been few intervention studies to test risk factors associated with lameness in dairy cows. All those published, except one, have used the traditional approach of testing one factor at a time. Hedges *et al* (2001) used a within-farm randomised control trial with farmers and veterinarians blind to treatment to test the effect of adding biotin to individual cows' feed on the incidence of claw lesions. There was a significant reduction in the incidence of white line disease of approximately 50% in cows which were fed biotin over 18 months. Manske *et al* (2002) carried out a clinical trial to test the effectiveness of two topical treatments for digital dermatitis (oxytetracycline and glutaraldehyde) applied to the claw during claw trimming. Topical treatment with oxytetracycline was the most effective treatment. The same authors also carried out a second clinical trial (Manske *et al* 2002) to test the efficacy of footbathing with acidic ionised copper compared with water, in which copper was more effective at resolving digital dermatitis.

Whilst changing one factor in a study gives a clear indication of whether the factor is associated with a change in outcome, it is an expensive approach and for diseases with many suspected risks that are not independent, one factor chosen might have a small or negligible effect on the incidence of disease when changed in isolation. It is therefore tempting to test many factors at once in a less controlled trial but where the results might be more useful. A similar multifactorial intervention study to the one described in this paper was carried out by Bell *et al* (2009) which tested change in management on lameness in dairy cattle. The researcher assessed locomotion and lesions on a proportion of heifers on 60 farms and provided the farm veterinarian with a control plan to make recommendations to reduce the incidence of lameness. After one year all heifers' locomotion and claw lesions in lame heifers were scored again. The intervention did not result in a significant decrease in the prevalence of lameness or the rate of sole ulcer, white line disease or digital dermatitis. Explanations for the lack of significant effect included low uptake of the control plan presented by the veterinarian and insufficient time for the farmers to make changes and for the changes to take effect. These authors did not suggest that the recommended changes might be ineffective.

One example of a clinical trial where several changes were recommended simultaneously that was successful was that used to test best practice to minimise mastitis in dairy cows in 26 intervention and 26 control herds. The percentage of cows affected with clinical mastitis and the herd somatic cell count were both reduced significantly by 22% (Green *et al* 2007). This best practice programme is now being rolled out in a nationwide programme in the UK.

Recommendations from risk factor studies that potentially reduce the risk of lameness can be considered broadly as those that require a change in management, eg gathering fewer cows at a time for milking or changing cow flow around a farm; those that require a small capital cost, eg addition of more bedding, scraping yards twice a day versus once and those that require considerable capital investment including improving the quality of concrete floors by resurfacing, change of floor surfaces in walkways, eg to slats or rubber coated, improving drainage of walkways and yards or improving cubicle housing by changing cubicle number, size, location or lying surface. There are no published costs or benefits available for such changes in management or resource, and indeed, they would vary by farm, however, it is highly likely that farmers are more likely to implement quick or cheap changes rather than time consuming or expensive ones. As importantly, because there is little scientific evidence for the optimum physical environment for dairy cows that minimises lameness, farmers might be reluctant to change their management at all.

As part of a three-year EU-funded project, 50 dairy cattle herds in England were enrolled into a longitudinal study in 2003. The current paper presents the approach and results from a one-year intervention study carried out from November 2005–January 2006. The aim was to investigate whether and how farmers took up recommendations to reduce lameness and what impact implementing these changes had on lameness. These recommendations were based on our current understanding, from our work and others, of potential risks in the farm environment likely to cause lameness. There are several differences between the study of Bell *et al* (2009) and the one described here. Bell *et al* studied a sample of first parity cows only and their locomotion was scored by the researcher once a year. All lame cows were examined and foot lesions diagnosed by the researcher who was a veterinarian. In the current study the locomotion of all adult cows in the milking herd was scored on four occasions by researchers and the lesions of all lame cows were diagnosed and recorded by the farmers.

Materials and methods

In the first year of the longitudinal study the 50 farms were visited on four occasions and each cow's locomotion was scored. The methods used to collect locomotion scores and lesion records throughout the study are described in full in Barker *et al* (2007, 2009). In summary, the locomotion of all cows in the herd were scored using a three-point scale simplified from Sprecher *et al* (1997) where sound cows had a level spine when walking and standing, cows with abnormal locomotion had an arched spine when walking but level spine when standing and severely lame cows walked and stood with an arched spine. The same two researchers scored all cows jointly on all farms and visits. Claw lesions were recorded by the farmer during normal farm treatment procedures on a standardised form which included a diagram of the claw to reduce misdiagnosis. Farmers were trained to identify lameness and were asked to record the cause of lameness on a standard form when they treated a lame cow. The herd's environment was assessed using a standard form and the farmer was interviewed (see Barker *et al* 2007, 2009 for details). In the second year of the study farmers were asked to continue to record causes of lameness in cows that they treated. The first year's data were analysed and potential risk factors for lameness and specific lesions associated with treatment were identified (Barker *et al* 2007, 2009). From these two studies an intervention plan was devised and tested on 22 of 40 farms that remained in the study for the third year. The study years 1, 2 and 3 were 1st February 2003 to 31st January 2004, February 2004 to 31st January 2005 and February 2005 to 31st January 2006, respectively. Data were used from all three years of the project using data from Barker *et al* (2007, 2009) and unpublished data from the second year of the study when there were no visits to the farms.

Allocation of farms to intervention and control groups

The farms were paired by matching on straw yard or cubicle housing, herd size, geographical location, mean locomotion score and rates of treatments for sole ulcer, white line disease and digital dermatitis. One farm from each pair was randomly allocated to an intervention group and the other to a control group by generation of a 0 1 Bernoulli distribution with $P = 0.5$ by a member of the group with little knowledge of the farms. The allocation was checked to ensure that the mean herd size, locomotion scores, lesion rates and geographical location were similar in each group.

Farmers were contacted by telephone to confirm that they wished to participate in this part of the study. They were made aware of which group they were in, 41 farmers agreed to participate in the study but one was subsequently dropped from the analysis due to a lack of lesion records.

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Table 1 Summary of five target areas for intervention and hypotheses and aims for reducing lameness.

Target area	Hypothesis	Aim
Cow comfort and standing times	Excessive standing increases risk of sole ulcer	Reduce involuntary standing times and encourage increased lying times
Floor quality and cow flow	Turning and slipping movements increase the risk of white line disease	Prevent sharp turns, avoidance behaviours and poor quality floors
Hygiene	Poor hygiene increases risk of infectious diseases	Reduce contact with potential pathogens in slurry
Footbathing and lameness control	Footbathing and individual treatment reduces risk of infectious lameness and prevalence of non-infectious causes	Reduce spread of infectious disease and improve recovery by treatment
Integration and socialisation	Poor integration and socialisation and integration of newly calved animals into the herd increases the risk of sole ulcer and white line disease	Reduce bullying that would lead to increased standing times and avoidance behaviours

Table 2 Mean (± SEM) incidence rate of sole ulcer, white line disease and digital dermatitis (per 100 cows per year) and mean (± SEM) prevalence of sound cows, cows with abnormal locomotion and severely lame cows (%) for 18 control and 22 intervention farms in three study years.

	Control			Intervention		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Sole ulcer	9.42 (± 2.05)	9.80 (± 2.50)	12.50 (± 3.75)	8.52 (± 1.64)	9.53 (± 1.80)	8.85 (± 1.49)
White line disease	8.11 (± 1.60)	6.58 (± 1.42)	7.36 (± 1.38)	7.41 (± 1.58)	8.50 (± 2.08)	8.47 (± 2.02)
Digital dermatitis	5.96 (± 1.73)	3.84 (± 0.85)	3.43 (± 1.32)	3.14 (± 3.13)	1.66 (± 2.54)	1.83 (± 0.97)
Sound	24.89 (± 2.30)	36.03 (± 2.48)	23.14 (± 6.81)	24.58 (± 2.03)	32.21 (± 2.14)	23.43 (± 1.62)
Abnormal locomotion	65.26 (± 1.82)	55.42 (± 1.63)	68.69 (± 1.41)	66.28 (± 1.45)	56.62 (± 1.83)	67.34 (± 1.26)
Severely lame	9.85 (± 2.08)	8.55 (± 1.63)	8.18 (± 1.86)	9.14 (± 1.22)	11.17 (± 1.51)	9.23 (± 1.60)

Intervention protocol

A form was developed to record the type of potential risks for lameness based on published literature. The risks were defined on five key areas (Table 1). A pilot visit was used to test and improve the form. The intervention farms were visited by a veterinarian (RB) and a researcher in November and December 2004. At the initial visit to the intervention farms RB and the researcher were guided around the farm by the farmer or herdsman following the route through the buildings that cows used each day as they were milked, fed and rested. The researcher recorded the presence and absence of risks on the recording form and noted recommendations as RB highlighted these to the farmer. Not all farmers were able to give complete details of the dairy ration when asked during the initial interviews of management practices completed during the summer of 2003. It was not feasible to sample and test the composition of the dairy ration for all farms due to cost and variation in feeding practices. Instead, RB asked the farmers about the incidences of dietary upsets during the visit and made a visual assessment of chop length. The forage in the feed troughs was also felt for signs of heat and other signs of poor forage management noted and discussed. On farms in the intervention group up to 16 recommendations were made to the farmer at the end of the inspection. The recommendations prioritised by RB were based on the rate of sole ulcer, white line disease and digital dermatitis on each farm. The farmer was asked to state whether he would be willing to implement each recommendation with a 'yes', 'might do' or 'no' response. This response was noted. A report of the visit detailing the points discussed and a list of the recommended changes was posted to the farmer within 14 days of the visit. A copy of the list of recommended changes was taken to the intervention farms at the subsequent three visits (occurring in the third and final year of the study) and the farmer was asked to provide details of all changes made.

In addition, at these visits, each cow's locomotion was scored and the recommended interventions followed up to see whether the changes had been made.

The control herds were also visited on three occasions in the third year of the study and the cows' locomotion and farm management observed. At the first visit risks present were recorded on the same form used on intervention farms by the researcher (in the absence of RB) but no recommendations were made. In the summer or autumn of 2006 the control farms received a fourth visit where RB made recommendations on reducing lameness as he had at the start of the study at the initial visit to intervention farms.

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Table 3 Changes in management recommended to farmers* to reduce the incidence of lameness and whether they were implemented on 22 intervention farms in England.

Management change recommended	Implemented		Farmer original response where management was changed			Farmer original response where recommendation was not implemented		
	n	Yes (%)	Yes	Might	No	Yes	Might	No
Decrease time cow standing around milking	4	3 (75.0)	1	1	1	0	0	1
Improve cubicle dimensions	27	7 (25.9)	3	4	0	5	10	5
Increase bedding in cubicles	14	6 (42.8)	6	0	0	4	1	0
Add mat/mattresses to cubicles	3	0 (0.0)	0	0	0	0	2	1
Increase number/replace cubicles	10	0 (0.0)	0	0	0	1	2	7
Increase width of passageways	12	0 (0.0)	0	0	0	0	0	12
Remove blind-ending passages	9	2 (22.2)	1	0	1	1	4	0
Increase feed space	6	2 (33.3)	0	1	0	1	0	3
Increase loafing space	3	1 (33.3)	1	0	0	0	1	1
Improve flow of cow in/out of parlour	8	2 (25.0)	2	0	0	1	1	4
Add rubber steps or turns	13	4 (30.8)	3	1	0	2	7	0
Remove (groove) slippery concrete	5	2 (40.0)	2	0	0	2	1	0
Removes pools of water in yards/passages	8	3 (37.5)	2	1	0	2	2	1
Repair/replace concrete	13	2 (15.4)	2	0	0	4	4	1
Improve surface of tracks/gateways	9	3 (33.3)	1	2	0	1	5	0
Improve methods of treatment of lame cows	6	3 (50.0)	3	0	0	2	1	0
Treat cows with DD individually	10	3 (30.0)	3	0	0	4	2	1
Increase the frequency of footbathing	18	4 (22.2)	4	0	0	9	4	1
Improve footbathing (location/type of bath)	6	2 (33.3)	2	0	0	1	3	0
Improve ventilation of house	8	2 (25.0)	2	0	0	0	5	1
Improve removal of slurry	10	4 (40.0)	2	1	1	4	1	0
Amend nutrition	10	6 (60.0)	5	1	0	2	2	0
Add biotin to ration	16	6 (37.5)	2	3	0	7	3	1
Train heifers to cubicles	7	2 (28.6)	1	1	0	0	4	1
Keep herd closed	7	6 (85.7)	5	1	0	1	0	0
Other	17	5 (29.4)	4	0	1	7	3	2
Total	**259**	**81**	**57**	**17**	**4**	**61**	**68**	**43**

* Four farmer responses not recorded (increase bedding, add biotin, increase feed space and improve slurry scraping, of which only the improvement to slurry scraping was not implemented).

Data analysis

The rates of sole ulcer, white line disease and digital dermatitis lesions were calculated as the number of lesions per 100 cows per year; only the first occurrence of a lesion was included. One farmer did not return any records of treatment of lame cows and so was excluded from the analysis. Locomotion scores recorded at the visits occurring between January to March 2004, January to February 2005, and January to February 2006 were used to represent the prevalence of lameness (ie the percentage of cows with abnormal locomotion or with severe lameness) in study years 1, 2 and 3, respectively. The change in rate of sole ulcer, white line disease and digital dermatitis and the change in prevalence of sound cows and severely lame cows between study years 1 to 2 and 2 to 3 were calculated for each farm.

The percentage of individual risks present on the farms that were addressed and the percentage of the risks highlighted to farmers in the intervention group that were addressed were calculated. Pearson's correlations were calculated for the relationship between the percentage of changes made and the change in incidence of sole ulcer, white line disease and digital dermatitis.

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The effect of farmers fully addressing a risk or not addressing a risk compared with not having a risk present was tested in a series of univariable Poisson analyses where the number of sole ulcers or white line lesions in study year 3 was the outcome variable. The expected rate of sole ulcer or white line disease in year 3 was included as an offset and the number of sole ulcers or white line lesions in study year 2 was added as a covariate. Where more than one risk in any one category existed, the risk was only considered fully addressed if the farmer addressed all risks present in that category. Where one or more risks were only partially addressed, eg additional bedding was added but not to the recommended level, the risk was classed as not addressed. Statistical analyses were carried out using MLwiN version 2.02 (Centre for Multilevel Modelling, University of Bristol, UK).

Results

The mean herd sizes were 122, 125 and 119 cows for control farms and 109, 109 and 107 cows for intervention farms for study years 1, 2 and 3, respectively. The lactation average milk yield per cow 8,157 litres for control and 7,807 litres for intervention farms in study year one. The mean rate of sole ulcer, white line disease and digital dermatitis for intervention and control farms in each of the study years are presented in Table 2. The mean prevalence of cows with sound, abnormal and severely lame locomotion for control and intervention farms in each of the study years is also presented in Table 2. Across the three visits taking place during year three, over 90% of the cows had abnormal locomotion or were severely lame on at least one visit and almost 50% were unsound at all three visits in that year.

Uptake of recommendations

There were 259 implementations suggested, 255 at the visit and four added to written reports (Table 3). The recommendations that were implemented on more than 50% of farms were to keep the herd closed, decrease the amount of time cattle stood before and after milking, improve nutrition and increase the amount of bedding (sawdust) in cubicles. The farmers were generally willing to make changes to the surface on which the cows stood and walked, eg treat slippery concrete, remove pooling of water in yards and passageways and improve tracks and gateways but were less willing or able to implement recommendations that necessitated replacing concrete. Similarly, no farmers increased the number of cubicles or replaced existing cubicles, added mats or mattresses to cubicles or increased the passage width. At the time the farmers were presented with these recommendations almost all indicated that they were not willing or able to make those changes (Table 3).

Reducing the risks for lameness

The median number of risks present on farms at the beginning of the intervention study was similar in intervention and control farms and the median percent of risks that were addressed by the farmers in the intervention group was greater than the control group (Table 4). The majority of risks addressed by the farmers in the intervention group had been highlighted by RB and a change recommended. The median number of risks present which were not highlighted by RB to the intervention farmers was 2.0 and therefore very few non-recommended risks were addressed by the intervention farmers (Table 4). Some farmers had made changes to their farms in year 1 or 2 of the study including seven farmers (two intervention, five control) who made substantial investments, eg new housing and six farmers (one intervention, five control) who made smaller investments, eg changes to routine management or buildings. In addition, four farmers (1 intervention, 3 control) made six changes to their farms which could have had detrimental effects on lameness (newly laid concrete, large increase in herd size including bought-in stock, purchase of poor quality batch of sawdust, use of road planings (a by-product of highway maintenance) on walking tracks, changing from deep-straw bedding to sawdust over mattresses in cubicles and introduction of automatic scrapers). Farmers in both intervention and control groups made other changes that might have impacted on lameness (intervention = 8, control = 9); for example, removing out of parlour feeders, extending the parlour and changing bedding type.

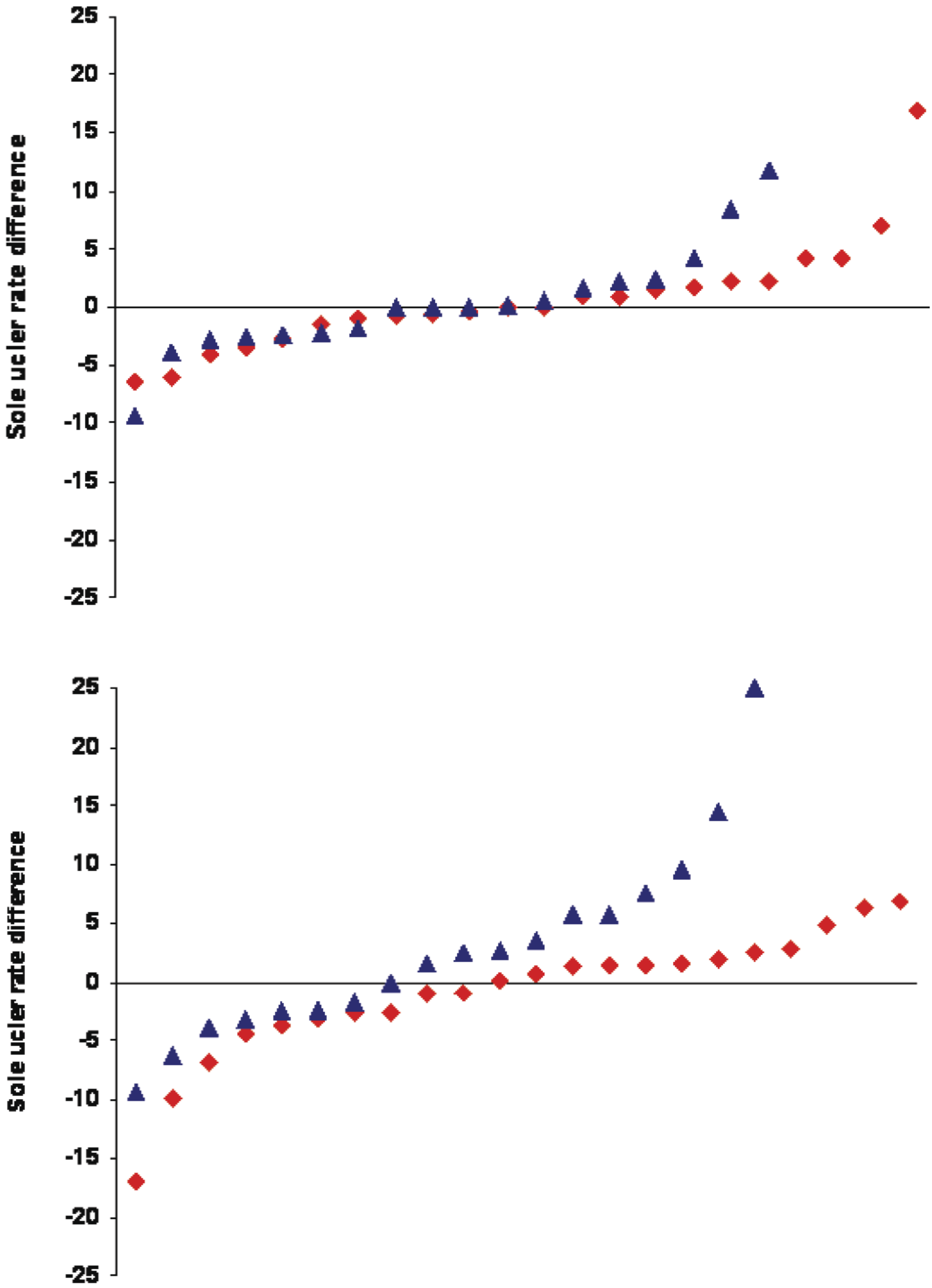
Table 4 Median and interquartile range of potential risks for lameness per farm at the start of the study and the number and percent of each addressed, by recommended for change or not.

	Intervention farms	Control farms
Overall risks present on-farm		
Median/farm	14 (11.3–17.0)	13 (10.5–16.5)
% risks changed	29.9 (19.4–38.5)	6.3 (0.0–13.3)
Risks not highlighted or recommended for change		
Median number	2 (1.0–4.8)	13 (10.5–16.5)
% risks changed	0.0 (0.0–83.3)	6.3 (0.0–13.3)
Risks highlighted and recommended for change		
Median/farm	11.5 (10.0–13.8)	n/a
% risks changed	36.9 (23.6–40.0)	n/a

Comparison of control and intervention groups

There were no significant differences between the control and intervention farms in terms of change in prevalence of lameness and the incidence rates of sole ulcer, white line disease and digital dermatitis between the different study years. However, some patterns are apparent when the data are represented graphically in Figures 1(a)–4(b). On farms where reductions in the rate of sole ulcer occurred the decrease was greater in herds in the intervention group than in the control group. Where the rate of sole ulcer increased the increases were smaller for farms in the intervention group than the control group (Figure 1[a], [b]). On farms where the rate of white line disease decreased after intervention it did so by a greater amount on intervention farms than control farms after the recommendations had been given compared with before (Figure 2[a], [b]). However,

Figure 1



Differences in rate of sole ulcer per 100 cows per year by farm between study years ranked by difference in rate (control farms = blue triangle, intervention farms = red diamond) showing (upper) Year 2–Year 1, before intervention and (lower) Year 3–Year 2, after intervention.

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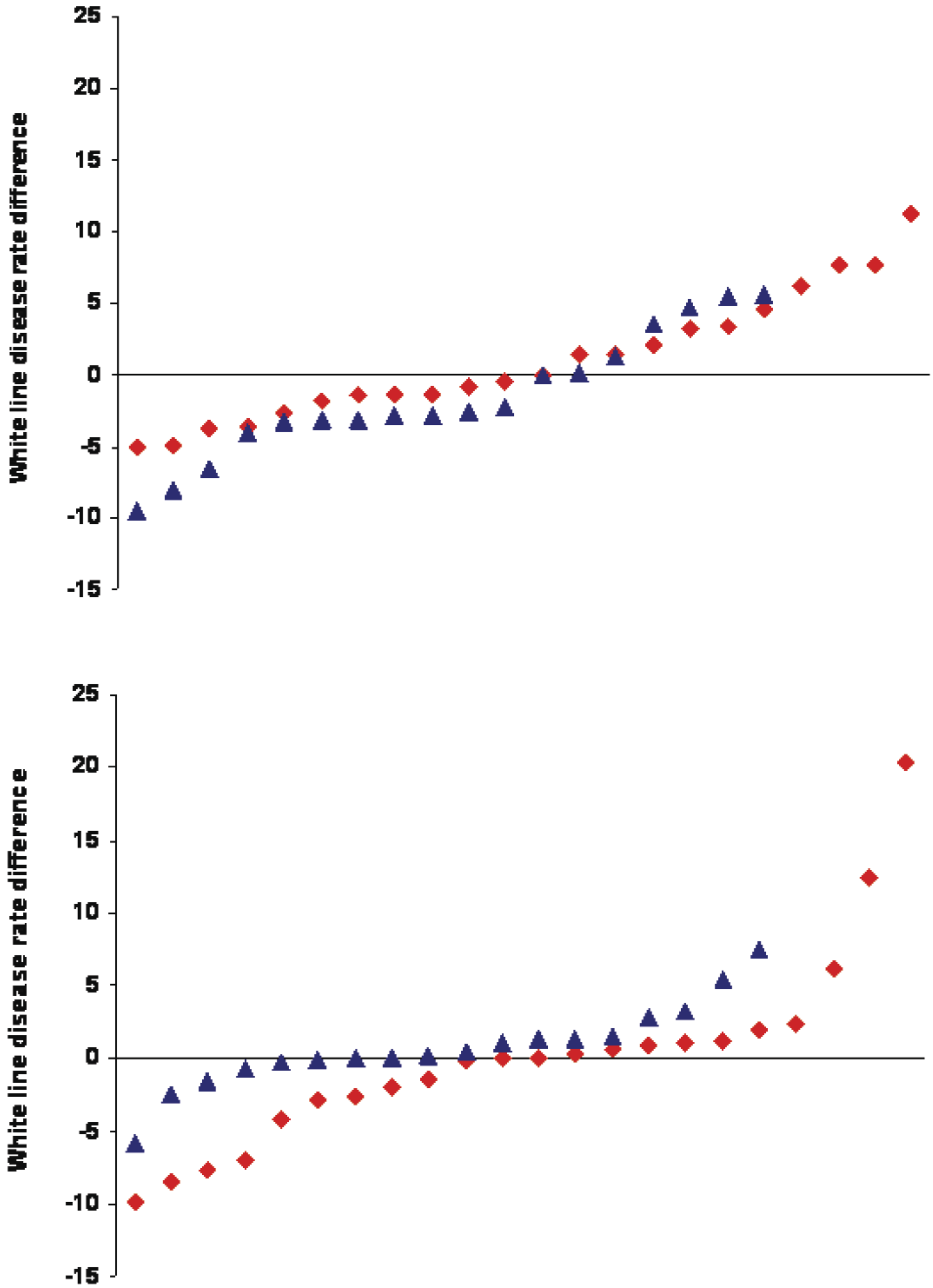
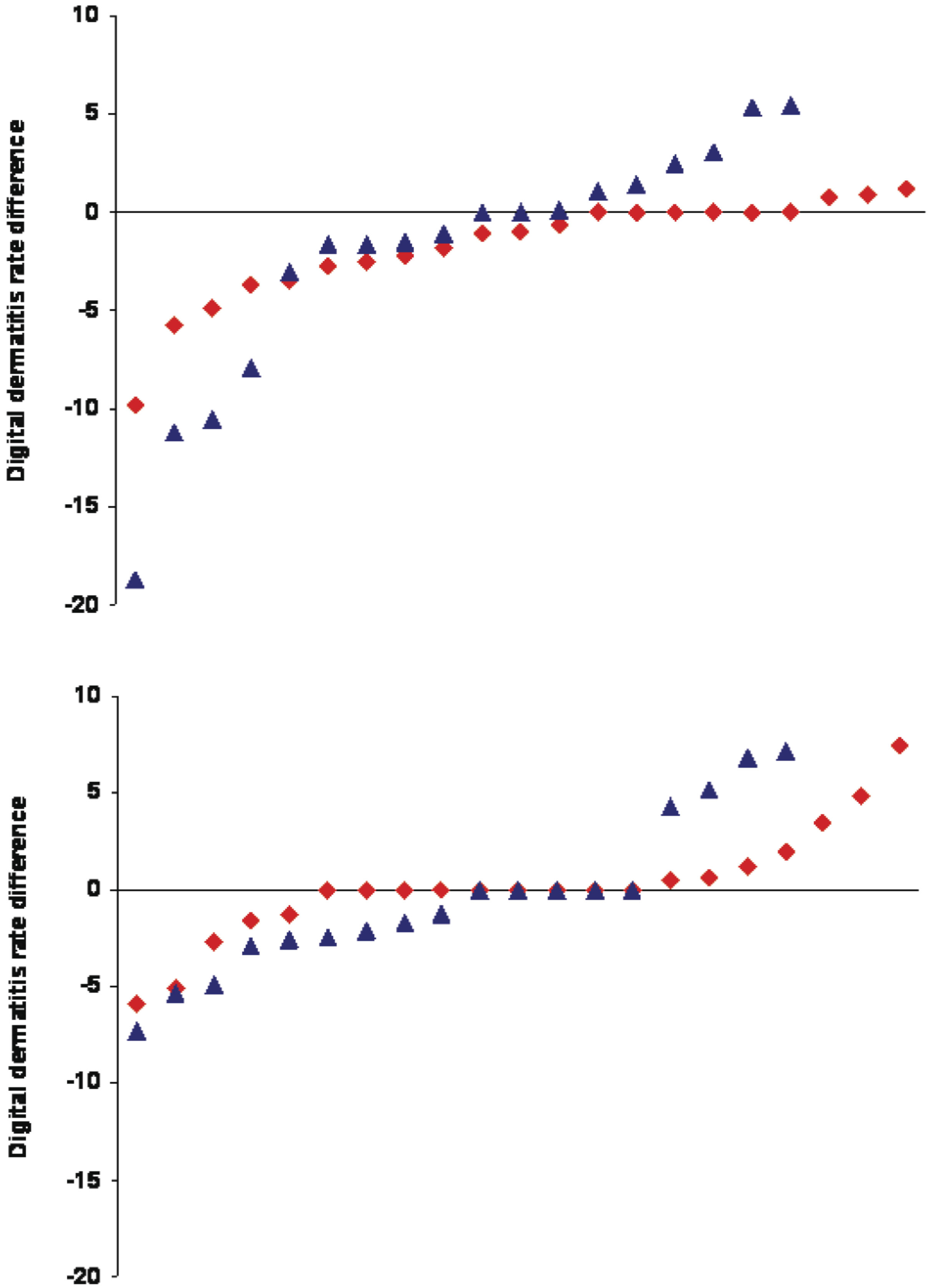
Figure 2



Difference in rate of white line disease per 100 cows per year by farm between study years (control farms = blue triangle, intervention farms = red diamond) showing (upper) Year 2–Year 1, before intervention and (lower) Year 3–Year 2, after intervention.

Figure 3



Difference in rate of digital dermatitis per 100 cows per year on each farm between study years sorted by difference in rate (control farms = blue triangle, intervention farms = red diamond) showing (upper) Year 2–Year 1, before intervention and (lower) Year–Year 2, after intervention.

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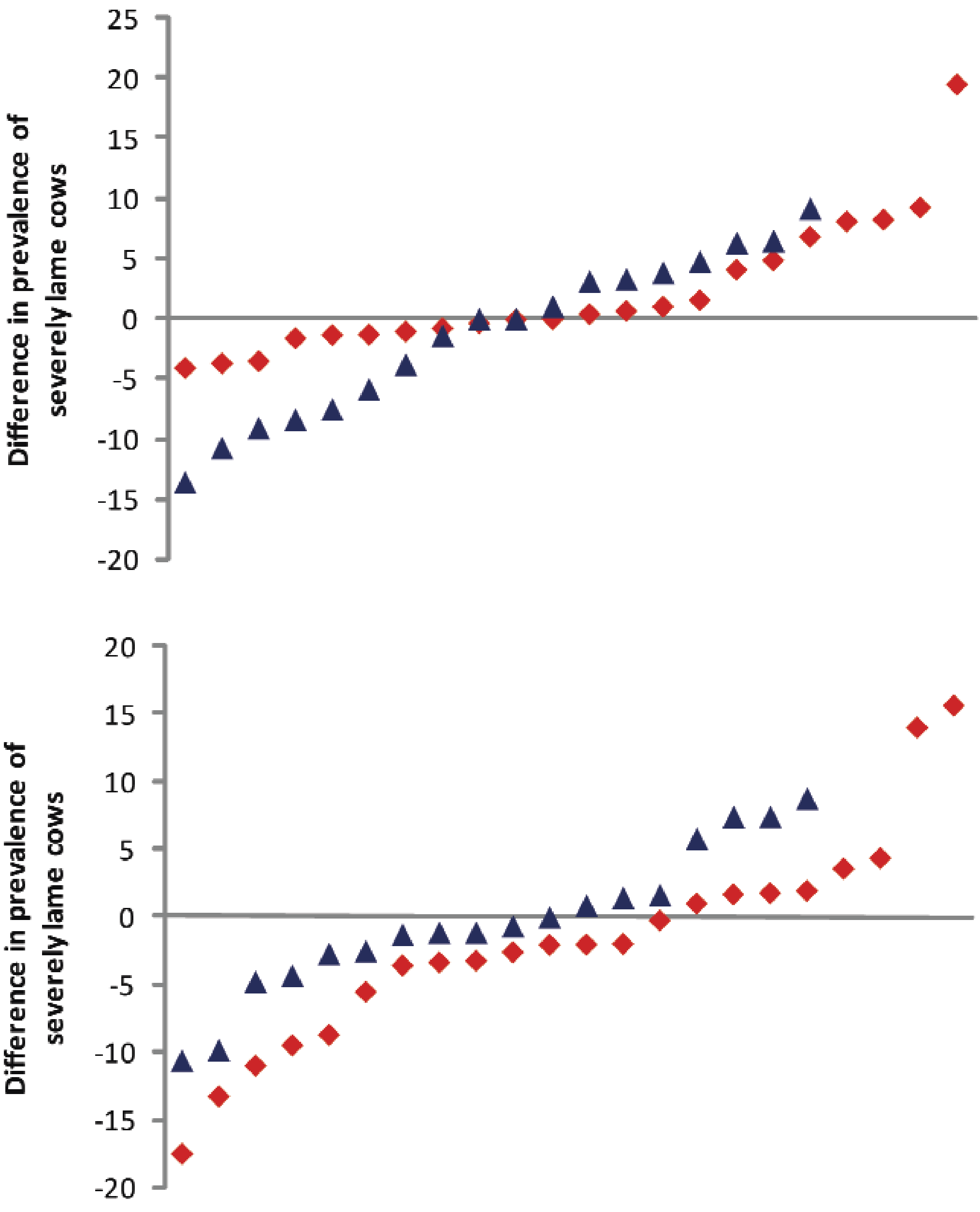
Figure 4



Difference in the prevalence of severely lame cows between study years ranked by difference (control farms = blue triangle, intervention farms = red diamond) showing (upper) Jan-Feb 2005–Jan-Mar 2004, before intervention and (lower) Jan-Feb 2006–Jan-Feb 2005, after intervention.

substantial increases in the rate of white line disease were recorded on two farms in the intervention group (Figure 2[b]). The incidence of digital dermatitis decreased after study year 1 for both intervention and control farms (Table 1). There were larger increases and smaller decreases in rate of digital dermatitis in the intervention group after interventions compared with before (Figure 3[a], [b]).

On farms where the percentage of severely lame cows decreased it was greater for intervention farms than for controls after interventions were implemented (Figure 4[a], [b]).

Relationship between changes made and claw lesions

There was a negative trend between the percentage of risks addressed and the change in incidence of white line disease ($r = -0.29$, $P = 0.01$). There were no such correlations between the percentage of changes made and sole ulcer or digital dermatitis. Increasing the quantity of bedding (sawdust) was associated with an increased risk of sole ulcer. Conversely, improving the dimensions of the cubicles was associated with a decreased risk of sole ulcer (Table 5). Increasing the quantity of bedding and

Table 5 Univariate Poisson analysis for the effect of removal or non-removal of risks for sole ulcer and white line disease on 40 farms.

		Rate ratio (95% confidence interval)	
Factor	**n**	**Sole ulcer**	**White line disease**
Improve cubicle dimensions			
Not a risk[1]	11	1.00	1.00
Risk not addressed	25	0.87 (0.68–1.11)	0.85 (0.65–1.11)
Risk fully addressed	4	0.57 (0.36–0.92)	1.94 (1.41–2.67)
Count of lesion in year 2		1.02 (1.02–1.03)	1.01 (1.01–1.01)
Increase bedding in cubicles			
Not a risk[1]	15	1.00	1.00
Risk not addressed	19	1.19 (0.94–1.50)	1.19 (0.93–1.53)
Risk fully addressed	6	1.51 (1.04–2.20)	2.41 (1.68–3.46)
Count of lesion in year 2		1.01 (1.01–1.02)	1.00 (1.00–1.01)
Remove (groove) slippery concrete[2]			
Not a risk[1]	19		1.00
Risk not addressed	18		1.31 (1.06–1.62)
Count of lesion in year 2			1.03 (1.02–1.04)
Remove blind-ending passageways[2]			
Not a risk[1]	24		1.00
Risk not addressed	14		0.64 (0.52–0.79)
Count of lesion in year 2			1.01 (1.01–1.02)
Improve flow of cows in/out of parlour			
Not a risk[1]	20		1.00
Risk not addressed	20		0.79 (0.64–0.98)
Count of lesion in year 2			1.01 (1.01–1.01)
Increase width of passageways			
Not a risk[1]	22		1.00
Risk not addressed	18		1.47 (1.20–1.81)
Count of lesion in year 2			1.01 (1.01–1.02)
Increase feed space			
Not a risk[1]	21	1.00	
Risk not addressed	15	0.76 (0.62–0.94)	
Risk fully addressed	4	1.10 (0.76–1.60)	
Count of lesion in year 2		1.02 (1.02–1.02)	
Add rubber steps or turns			
Not a risk[1]	28	1.00	1.00
Risk not addressed	8	1.29 (1.05–1.60)	0.61 (0.42–0.90)
Risk fully addressed	4	0.77 (0.54–1.11)	0.70 (0.43–1.15)
Count of lesion in year 2		1.02 (1.02–1.02)	1.02 (1.01–1.02)
Remove pools of water in yards/passageways[2]			
Not a risk[1]	21	1.00	
Risk not addressed	18	1.25 (1.02–1.54)	
Count of lesion in year 2		1.02 (1.02–1.02)	
Improve removal of slurry[2]			
Not a risk[1]	20		1.00
Risk not addressed	19		1.32 (1.06–1.64)
Count of lesion in year 2			1.01 (1.01–1.02)

[1] Reference category; [2] Univariate model adjusted for farms on which change was fully addressed.

Table 5 (cont)

		Rate ratio (95% confidence interval)	
Factor	**n**	**Sole ulcer**	**White line disease**
Increased frequency of footbathing			
Not a risk[1]	17		1.00
Risk not addressed	19		1.31 (1.01–1.69)
Risk fully addressed	4		1.36 (0.98–1.89)
Count of lesion in year 2			1.01 (1.01–1.01)
Improve methods of treatment of lame cows[2]			
Not a risk[1]	19		1.00
Risk not addressed	18		2.07 (1.64–2.60)
Count of lesion in year 2			1.01 (1.01–1.02)
Amend nutrition			
Not a risk[1]	29		1.00
Risk not addressed	6		0.79 (0.59–1.07)
Risk fully addressed	5		0.27 (0.16–0.45)
Count of lesion in year 2			1.02 (1.02–1.03)
Add biotin to ration			
Not a risk[1]	12		1.00
Risk not addressed	19		0.65 (0.52–0.82)
Risk fully addressed	9		0.54 (0.41–0.71)
Count of lesion in year 2			1.01 (1.01–1.02)
Other[2]			
Not a risk[1]	18		1.00
Risk not addressed	19		1.37 (1.08–1.74)
Count of lesion in year 2			1.01 (1.01–1.01)

improving the dimensions of the cubicles were both associated with an increased risk of white line disease. Amending the diet of some or all cows and adding biotin to the ration were both associated with a decreased risk for white line disease (Table 5). There were a greater number of significant associations between sole ulcer and white line disease and risks that the farmers did not address. The risk of sole ulcer increased when rubber was not added to steps and or sharp turns and when pooled slurry was not removed. Not increasing the amount of feed space was associated with decreased risk of sole ulcer (Table 5). There was an increased risk of white line disease associated with not implementing the following recommendations; grooving slippery concrete, increasing passageway width, improving slurry removal and not increasing the frequency of foot-bathing (Table 5). There was a decreased risk of white line disease associated with not removing blind-ended passageways, not improving cow flow through the parlour, not increasing the width of passageways, not adding rubber to steps or sharp turns and not adding biotin to the ration (Table 5).

Discussion

The lack of significant reductions in lameness on farms receiving a list of recommendations compared with farms that did not is in common with a similar study of lameness in first parity cows (Bell *et al* 2009). In both studies, the prevalence of lameness and incidence of lesions were measured and an assessment of the risks present on the farms were used to guide the recommendations provided to the farmer and the effect of these interventions were followed over one year. There are a number of explanations for the lack of effect in the current study which are discussed below. These include; the study design failed to measure an effect that was truly present; the number and the type of recommendations implemented by farmers was not sufficient; a one-year intervention study was insufficient duration and the recommendations themselves were not causally related to the prevalence or incidence of lameness.

One difference between the study of mastitis by Green *et al* (2007), where implementing risk-based recommendations was associated with a reduction in mastitis, and this study might be the relative ease of detecting a case of mastitis compared with detecting a lame cow, which depends on farmer observation (Leach *et al* 2010). Treatment, diagnosis and recording of lesions cannot occur until a cow has been identified as lame by the farmer, the speed of this varies by farmer (Leach *et al* 2012). Although the recording forms used to capture the lesions' records were designed to minimise errors it is possible that not all diagnoses by the farmers were correct and that these errors may have varied with time. These facts might have underestimated the incidence of lesions and might have done so in an inconsistent manner between farms. This will have created bias and/or measurement error that would have reduced the power of the study offering one explanation for why a significant effect of treatment was reported by Green *et al* (2007) for mastitis but no such result was observed in this study for lameness. This bias may have been reduced in the current study because farmers were trained to identify foot lesions but this was not formally assessed. A better approach would have been if researchers had carried out foot inspections on the farms. The time constraints of visiting all farms in this study prevented the researchers from doing this. Evidence against this argument is that in the study of heifer lameness by Bell *et al* (2009), the research team carried out foot inspections to determine the type of lesions but their study also failed to detect a reduction in lameness.

The mean prevalence of severely lame cows was typically between 8 and 11% for each of the study years prior to intervention compared with a mean baseline prevalence of 5.3% reported by Barker *et al* (2010) for a similar study which used a four-point score for locomotion. The use of a three-point score based only on arching of the spine resulted in a large proportion of cows having abnormal locomotion score 2. If the scoring system used in this study is compared directly with the one used by Barker *et al* (2010) it is likely that most score 2 (lame) cows and large number of score 1 (imperfect locomotion) in Barker *et al* (2010) would have been score 2 in the current paper, explaining the high prevalence of cows with abnormal locomotion. The variability of scores in a three-point scale may have been lower than a four-point scale and this may also have contributed to the lack of significant differences between intervention and control groups.

One major difference between the Green *et al* (2007) mastitis study and the current study was the wealth of information on risks for mastitis that have been published as clinical trials over the years. The result of this lack of such information for the current study and that of Bell *et al* (2009) is that the changes in management proposed were based on suspected risk rather than known risks.

Green *et al* (2007) reported a greater reduction in mastitis as the number of recommendations implemented increased: nine of the 26 intervention farmers implemented over two-thirds of the recommendations to reduce mastitis and only one of those nine farms failed to reduce mastitis incidence. None of the 22 interventions farms in the current study implemented more than two-thirds of recommendations which might explain partly why there were no correlations between the overall percentage of recommendations implemented and prevalence of lameness or incidence of sole ulcer or digital dermatitis in this study and only a weak association with the incidence of white line disease. The reduced uptake, combined with slightly fewer farms in the two treatment groups compared with that of Green *et al* (2007) also resulted in a mathematically lower number of changes especially within specific types of intervention. The factors which motivate farmers to increase their uptake of interventions for lameness are likely to be complicated but one possible factor is a lack of understanding of the effects of lameness on a farm business (Leach *et al* 2010). Unlike mastitis, most of the economic losses associated with lameness are indirect (Kossabaitati & Esslemont 1997) and so the motivation to minimise lameness might be lower. In the study by Green *et al* (2007) fewer interventions that were recommended required large capital investments than in this study and this may also explain the greater uptake of recommendations reported. In the current study, farmers made changes that were easy to implement, eg reducing the time standing for milking, increasing bedding on cubicles and changes to nutrition. Where changes with a greater cost were made they tended to have a more obvious and direct link to claw health, eg improving tracks and treating slippery concrete. The methods by which the recommendations were delivered to the farmers were similar to that of Green *et al* (2007) and Bell *et al* (2009), however in recent years greater attention has been focused on how we communicate with farmers. Jansen *et al* (2010) grouped farmers based on their attitudes towards gathering and using information about udder health and suggested that different methods of communication with these groups of farmers are likely to be required to achieve the greatest impact. A range of communication methods were utilised in a three-year lameness intervention study involving 189 dairy farms (Main *et al* 2012). A greater number of changes were made by the farmers in the treatment group which received this support compared with the control group that did not. Despite this, the effect on lameness prevalence of the two treatments was not significant.

It was important to test the effect of giving recommendations to farmers and the resulting impact on lameness on commercial farms rather than experimental farms, however, this meant that, in addition to uptake of recommendations, a number of other factors could not be controlled. First, it was not possible to prevent farmers in the control group from making changes that might influence the prevalence and incidence of lameness as all farms in the study were commercial units. Approximately 6% of risks for lameness on control farms were addressed by the farmers which would have diluted the effect of the interventions made. Second, it was not possible to control the choice of changes made by the farmers some of which may have a greater effect on lameness than others. Due to the lack of number of each type of change implemented it was only possible to test the effect of implementing a small number of the recommendations. It is therefore not possible to suggest which recommendations had the greatest impact on lameness from this study. Finally, it is likely that the

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standard to which the recommendations were implemented and maintained on farms varied. It was not always possible to measure how well every intervention had been implemented and maintained between visits to the farm and so the impact of this effect is unknown.

The duration of the intervention study was short and with exposure to some risks being seasonal, eg use of walkways only occurs in summer, a longer study might have led to more significant changes in lameness. In addition, some changes were made part-way through the study, eg many changes to housing were not implemented until the summer grazing period while the housing was empty (also mooted by Bell *et al* 2009) and so cattle were exposed to the new environment for only four months. The effects of the short study duration could have been further exacerbated by the main focus of the recommendations being reducing the risks present to prevent new cases of lameness. Only a small proportion of the recommendations were related to the treatment of lame cows. To measure an effect of implementing a preventive intervention it would have been necessary to have sufficient non-lame cows and enough time for a lesion to develop. Implementing interventions which improve the treatment of lame cows is likely to have improved recovery from lameness however, if recommendations on improved treatment of lame cows had resulted in a reduced time to treatment then it is likely that the incidence of lameness would have increased at least in the first instance.

The effect of individual recommendations implemented by farmers on sole ulcer and white line disease were not always in the direction expected, indicating that some of the recommendations given to farmers may not be beneficial. Improving the cubicle dimensions to improve comfort and therefore lying times was associated with a reduction in sole ulcer rate but increasing rate of white line disease. The explanation for this is unclear. Adding bedding to the cubicle was associated with an increase in rate of sole ulcer and white line disease. Recent papers have drawn a distinction between deep bedding and shallow or abrasive bedding and unabrasive bedding (Dippel *et al* 2009; Barker *et al* 2011). In the current study, most of the recommendations for increasing bedding were given to farmers who were using sawdust. Perhaps it is not surprising that increasing the quantity of this potentially abrasive bedding does not reduce sole ulcer or white line disease. This certainly warrants further investigation and current recommendations should consider the quality of bedding materials as well as the depth. Recommendations for improving nutrition were often aimed at improving the transition of heifers and dry cows into the milking herd and appear to have been successful in reducing white line disease.

The effect of not making changes, ie leaving a risk present on the farm compared with farms which were not considered to have specific risks, were also tested and produced a number of results which compare with risks for lameness or specific lesions identified in the literature. Moisture content of sole horn has been reported as an important factor for increased wear leading to thin soles (Van Amstel *et al* 2004) and increased severity of claw lesions (Borderas *et al* 2004). This might explain the increase in sole ulcer rate associated with not reducing pooling on farms in the current study. Anecdotally, a number of veterinarians have suggested that there is an increase in complicated, including severe, white line lesions where digital dermatitis is not controlled on the farm. This may explain the increases in white line disease associated with not improving slurry management and not increasing the frequency of footbathing. It is likely that slipping and attempting to regain balance or standing up after a fall would all result in increased shearing forces on the claw and pressure on the white line explaining the association between not reducing the slipperiness of concrete floors and an increased rate of white line disease. The recommendations to reduce blind-ended passageways, improve cow flow into and out of the parlour and increase the width of passageways were also aimed at reducing potential shearing forces by reducing the number of twisting and turning movements that cows make which we hypothesised were associated with white line disease. Not making these recommendations was associated with reduced white line disease suggesting that either our hypotheses were not correct or that our assessment of the risks was not sufficiently accurate. These recommendations were based on observations of the buildings rather than visual assessments of how the cows use the space. Greater observations of cow behaviours may be required during the process of assessing risks.

Animal welfare implications

Lameness is a painful condition (Whay *et al* 1997). A large number of cows were lame during this intervention study with half being score 2 or 3 for all three visits. This represents a large number of cows lame and, by inference, in pain for an extended period of time. It is therefore essential to find ways by which the incidence and prevalence of lameness can be reduced.

Conclusion

Farmers who were given recommendations aimed at reducing lameness by a veterinarian did not reduce the prevalence of lameness or incidence of sole ulcer, white line disease or digital dermatitis (the three most common lesions) compared with farmers that received no such recommendations. There were small significant associations between specific types of changes and a reduction in the rate of sole ulcer or white line disease, however, the direction of these associations was not always as expected. Low uptake of recommendations, a short recording period, lack of accuracy of recording data and inappropriate identification of risks may have contributed to the overall lack of effect. Future studies should focus on testing individual interventions.

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