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

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10

11 **Abstract**

12 The aim of this study was to investigate whether the risk factors associated with all
13 causes of lameness in sheep differed from those associated with the lesion specific
14 causes of lameness, interdigital dermatitis (ID) and footrot (FR). A total of 809
15 randomly selected English sheep farmers participated in a postal survey in 2005. Data
16 were requested on their management of lameness in 2004 and whether this had
17 changed from 2003 and the prevalence of all lameness, and lameness caused by ID
18 and FR. The farmer ability to recognise ID and FR was assessed from their responses
19 to a written and pictorial description. On 443 farms where both ID and FR were
20 correctly named by the farmer, the mean prevalence of all lameness, and lameness
21 caused by ID and FR were 10.0% (95% CI: 8.9, 10.8), 6.5% (95% CI: 5.8, 7.3) and
22 3.1% (95% CI: 2.8, 3.6) respectively. The mean prevalence of all lameness on all 809
23 farms was not significantly different at 10.2% (95% CI: 9.2, 11.0). The data were
24 analysed using negative binomial regression models with the three outcomes farmer
25 estimated prevalence of all lameness and lameness caused by ID or FR in 2004.
26 Farmers who changed management of sheep between 2003 and 2004 were excluded
27 from the analysis, thus all fixed effects were the farmers' managements in 2003 and
28 2004 to ensure that the management was in place for at least one year before the
29 prevalence estimates.

30 Routine foot trimming \geq once/year compared with no routine foot trimming was
31 significantly associated with an increased prevalence of all lameness (prevalence ratio
32 (PR)=1.34, $p<0.01$), ID (PR=1.50, $p<0.01$) and FR (PR=1.35, $p=0.02$). Footbathing
33 was also significantly associated with increased prevalence of all lameness (PR=1.67,
34 $p<0.01$), ID (PR=1.68 <0.01) and FR (PR=1.76, $p<0.01$). A stocking density
35 of >8 ewes/ha was associated with a significantly increased prevalence of all lameness

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

44

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

47

48 **1. Introduction**

49 Footrot (FR) and interdigital dermatitis (ID) are the two most common causes of
50 lameness in sheep in the UK (Kaler and Green, 2008a), causing approximately 80% of
51 lameness. Although clinically distinct, these two foot lesions are aetiologically linked
52 and represent a continuum of foot damage from mild irritation of the interdigital skin
53 to clinical interdigital dermatitis (ID) and then separation of the hoof horn (FR) as a
54 damaged foot with no bacterial proliferation is invaded by ubiquitous *Fusobacterium*
55 *necrophorum* followed by invasion with *Dichelobacter nodosus* (Egerton et al., 1969).
56 The clinical distinction between ID and FR is not well correlated with the bacterial
57 distinction with 60% of sheep with ID culture positive for *D. nodosus* (Moore et al.,
58 2005).

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

70 In 2000, a study of 251 non - randomly selected sheep farmers in England and Wales
71 was conducted by Wassink et al. (2003, 2004) to investigate farmers' management

72 practices and their associations with the prevalence of FR and ID in their flock. In
73 Wassink et al. (2003, 2004) questionnaire, farmers were asked to list the prevalence of
74 FR and ID for each month of 2000. The highest monthly prevalence of FR and ID was
75 then used in subsequent analyses. Factors associated with an increase in the
76 prevalence of ID in ewes were ‘sometimes/never’ catching lame sheep compared with
77 ‘always’, farm land 100m or less above sea level and renting–in winter grazing
78 (Wassink et al., 2004). The factor associated with an increased prevalence of FR was
79 routine foot trimming. The factors associated with a decrease in prevalence of FR
80 were isolation of brought-in sheep; individual treatment of diseased sheep with
81 parenteral antibiotic, foot trimming individual lame sheep and topical foot spray.
82 There was no significant association between footbathing or vaccination and the
83 prevalence of FR or ID in the flock (Wassink et al., 2003; 2004).

84 One limitation of the study carried out by Wassink et al. (2003, 2004) was that it used
85 a non random sample of farmers, which affected the generalisability of the prevalence
86 estimates. Two assumptions were that farmers could correctly recognise lame sheep
87 and the causes of lameness and that there was a link between the managements in
88 2000 and disease in 2000. Consequently, when a study of randomly selected English
89 sheep farmers (Kaler and Green, 2008a) was conducted to investigate farmer ability to
90 recognise and name six common foot lesions of sheep the opportunity was taken to
91 assess the managements associated with the prevalence of lameness on these farms.
92 Approximately 83% and 85% of farmers correctly named ID and FR respectively
93 (Kaler and Green, 2008a). There is also now evidence that farmers can identify lame
94 sheep, at least from movie clips of sheep with a range of locomotion scores (Kaler and
95 Green, 2008b) and can recognise, but not necessarily correctly name, common foot
96 lesions (Kaler and Green, 2008a).

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

102

103 **2. Materials and Methods**

104 *2.1. Data collection*

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

118 *2.2. Farms selected for analysis*

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

130 *2.3. Statistical analysis*

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

134 *2.3.1. Model building strategies*

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

142 **Number of cases on farm_j in 2004 ~ α + offset + βX_j + e_j**

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

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

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

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

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

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

178 **3. Results**

179 *3.1. Selected farms*

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

188 3.2. *General farm characteristics (all farms irrespective of recognition of lesions:*

189 *Dataset A)*

190 Approximately 65% (472/727) of the farmers had a flock size of ≤ 300 ewes (Table 2).

191 The number of ewes less than one year of age ranged from 0 to 1200 with a median of

192 15. The median number of rams \geq one year of age was 6 (inter-quartile range 3-13).

193 Farmers reported very few rams less than one year of age in their flocks, with a

194 median value of 0 (inter-quartile range 0-2). The median number of meat lambs sold

195 and lambs still on the farm, but not finished (ready for slaughter) by the end of

196 December 2004 were 279 and 20, respectively.

197 Mule was the most common ewe breed and was present on 60% (442/730) of farms.

198 Approximately 50% of farmers reported the presence of 'other' breeds on their farm

199 which included a variety of ewe breeds and breed crosses; the most common were

200 Suffolk cross and Swaledale. The most common ram breeds were Suffolk and Texel

201 respectively, on 407 (57%) and 364 (51%) farms out of 715. A total of 250 (35%)

202 farms had 'other' breeds which included Swaledale, Lleyn, Beltex and Polled Dorset.

203 Lameness management practices of the farmers are described in Table 2. The

204 distributions of farmers' practices and flock structure were fairly similar for the

205 farmers who did and did not correctly identify ID and FR (Table 2).

206 3.3. *Prevalence of lameness, ID and FR*

207 Ninety seven percent of 737 farmers reported that they had lame sheep in their flock

208 in 2004. The overall mean prevalence of lameness per farm in 2004, irrespective of

209 farmer lesion recognition (Dataset A), was 10.2% (95% CI: 9.2, 11.0) (Figure 1). On

210 farms where both ID and FR were correctly identified, 96% (346/362) and 93%

211 (318/341) of farmers reported the presence of ID and FR respectively. The mean

212 prevalence of ID and FR (Dataset B) was 6.5% (95% CI: 5.8, 7.3) and 3.1% (95% CI:
213 2.8, 3.6) respectively (Figure 1) and the mean overall lameness was 10.0 (95% CI: 8.9,
214 10.8). On farms where both lesions were correctly identified 10 out of 339 farmers
215 reported FR but no ID and similarly there were 23 farms where ID was present
216 without FR. There was no obvious association between the prevalence of FR and ID
217 within these farms in 2004 (Figure 2).

218 *3.4. Negative binomial regression models for lameness, ID and FR*

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

224 The prevalence ratios (PR) for lameness, ID and FR where farmers routinely trimmed
225 the feet of their flock once or more per year compared with those who did not
226 routinely trim at all were 1.34 (95% CI: 1.15, 1.55) , 1.50 (95% CI: 1.18, 1.90) and
227 1.35 (95% CI: 1.03, 1.78) respectively. In all three models, the frequency of
228 footbathing was significantly associated with the prevalence of lameness, ID and FR.
229 Farmers who foot bathed their sheep once every 2 – 4 weeks had a significantly
230 higher prevalence of lameness, ID and FR compared with those who did not footbath
231 their sheep (PR: lameness = 1.67 (95% CI: 1.43, 1.95); ID =1.68 (95% CI: 1.30, 2.16);
232 FR =1.76 (95% CI: 1.30, 2.37)) respectively. In addition, footbathing once every 3 -
233 12 months (PR= 1.26 (95% CI: 1.07, 1.48)) and ‘when necessary’ (PR= 1.47 (95% CI:
234 1.15, 1.88)) were significantly associated with a higher prevalence of all lameness
235 compared with never footbathing and the trends were similar for ID and FR (Table 3).

236 Farmers who separated ‘some’ or ‘all’ of their lame sheep at pasture had lower PR for
237 lameness and ID compared with those who separated none of their lame sheep of 0.75
238 (95% CI: 0.65, 0.87) and 0.73 (95% CI: 0.58, 0.92) respectively. Farmers who had a
239 stocking density of >8 ewes/ha compared with farmers that had stocking density of ≤8
240 ewes/ha had a PR for lameness and ID of 1.26 (95% CI: 1.05, 1.50) and 1.39 (95% CI:
241 1.09, 1.82) respectively. There was no significant association between separation of
242 lame sheep or stocking density and the prevalence of FR.

243 The south east of England had a significantly lower PR for lameness, ID and FR
244 compared with central England of 0.75 (95% CI: 0.61, 0.93), 0.71 (95% CI: 0.52, 1.00)
245 and 0.70 (95% CI: 0.48, 0.99) respectively. In addition, the north east of England also
246 had a significantly low PR for FR compared with the central region of 0.73 (95% CI:
247 0.53, 0.93). There was no evidence for confounding or interaction between variables
248 in the final models.

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

256 **4. Discussion**

257 The risk factors for both ID and FR were investigated separately to differentiate the
258 possible risks for lameness caused by each lesion and to see whether management
259 factors were associated with specific presentations of lameness. Although there was a

260 difference in factors significantly associated with both these conditions (Table 3), the
261 associations were in a similar direction for nearly all factors for ID and FR. The
262 failure to detect a significant association between some variables that were
263 significantly associated with ID and FR might have occurred because there was less
264 power in the FR model because the prevalence of FR was lower. The factors
265 significantly associated with the prevalence of lameness were, in fact, a combination
266 of factors associated with prevalence of ID and FR; this reiterates the importance of
267 ID and FR as the most common causes of lameness in sheep flocks. This is a useful
268 result because we can target management of lameness and, if farmers know that they
269 have FR and ID in their flock (and over 90% do) then we can test interventions that
270 will reduce lameness.

271 Only farmers who did not change their management between 2003 and 2004 were
272 included in the current analysis to avoid the risk that a high prevalence of lameness
273 had caused a management practice. This was an improvement on Wassink et al. (2003,
274 2004) where the lameness management and lameness estimates were collected for the
275 same year. Thus, the reported associations between certain management factors and
276 lameness in previous studies could have been because high lameness led farmers to
277 choose a management approach.

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

284 these farmers had mis-diagnosed FR, despite their apparent ability to recognise FR in
285 the questionnaire.

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

294 Several limitations should be considered when interpreting results from the current
295 study. Although the farms in both Datasets A and B were similar in regional
296 distribution and flock size ($p > 0.05$), they differed significantly ($p < 0.05$) from the
297 DEFRA (Department of Environment, Food and Rural Affairs) agricultural census of
298 2004 with respect to flock size and geographical location (Kaler and Green, 2008a).
299 Also, although there was no significant difference between respondents and non-
300 respondents with respect to geographical location and flock size (Kaler and Green,
301 2008a), there is a possibility of non response bias in the overall response to the survey
302 (e.g. it might be that farmers that had higher levels of lameness/ID/FR preferentially
303 responded to the survey) and to specific questions, although the response rate to most
304 questions was very high ($> 85\%$). Finally, all the questions were asked for the previous
305 year, thus there is the possibility of recall bias.

306 The prevalence of lameness, ID and FR were significantly lower in eastern England.
307 Wassink et al. (2003), also reported a lower prevalence of FR in the east of England,

308 where there are warmer summers, colder winters and lower average rainfall compared
309 with other parts of England (Anon., 2004). This adds to the evidence for the
310 importance of warm, wet conditions for the transmission and expression of FR (Green
311 and George, 2008), in addition to the inflammation of interdigital skin (Beveridge,
312 1941; Parsonson et al., 1967; Roberts and Egerton, 1969).

313 A high stocking density of > 8 ewes/ha and separating 'some or all' lame sheep at
314 pasture / housing that were significantly associated with higher and lower prevalence
315 of both lameness and ID respectively, and the trend was similar for FR. Wassink et al.
316 (2003) reported a lower prevalence of FR in flocks where farmers separated sheep
317 with FR and it is probable that ID will also be controlled by this management when *D.*
318 *nodosus* is present, due to the clinical link between ID and FR (Moore et al., 2005).
319 More speculatively, the low prevalence of ID associated with separating lame sheep
320 might be due to overload of the pasture with *F. necrophorum* (also reinforced by the
321 association between high stocking density and ID) and thus separating lame sheep
322 reduces this accumulation of *F. necrophorum*.

323 In contrast to the results published by Wassink et al. (2003) and Green et al. (2007),
324 none of the individual treatments for diseased sheep i.e. foot trimming, parental
325 antibiotic injections and topical sprays were significantly associated with the
326 prevalence of lameness, ID or FR. There may be several reasons for this lack of
327 association. The prevalence estimates requested from farmers in the current study
328 were an average for the whole year, whilst Wassink et al. (2003, 2004) requested
329 estimates of ID and FR in each month of the year and used the highest monthly
330 prevalence over the year in the analysis. The overall variation in the reported
331 prevalence of ID and FR among farmers in the current study was much less than that

332 reported by Wassink et al. (2003, 2004) which might be a limiting factor in the current
333 study and the greater variability in Wassink et al. (2003, 2004) might have highlighted
334 that individual treatments were reducing the peak of mini-epidemics of FR or ID. This
335 would occur if treatments were prompt. Thus, it is not only ‘always’ using parenteral
336 antibiotics and topical sprays that helps to reduce the prevalence and incidence of
337 infectious lameness but also the ‘timely’ use of this approach (Green et al., 2007;
338 Hawker, 2008). Unfortunately, we did not ask about frequency and time to treatment.
339 In addition, the questions regarding individual treatments were asked in a different
340 way in the two questionnaires. Wassink et al. (2003, 2004) asked farmers whether
341 they ‘always’ ‘sometimes’ or ‘never’ used various individual treatments to treat their
342 sheep with FR. In the current study, farmers were asked to give a percentage of their
343 lame sheep that they treated with each of the individual treatments (Table 1). The aim
344 of this question was to increase precision, but it might be that, although apparently
345 more precise, ironically farmers were less able to answer the question precisely or
346 might have interpreted the question differently.

347 In the current study, routine trimming was significantly associated with an increased
348 prevalence of ID, FR and lameness. The results suggest that even routine trimming
349 once per year is associated with an increased risk of lameness; this is different from
350 Wassink et al. (2003) where a positive association between routine trimming more
351 than once a year and FR was reported. A second new result from the current study is
352 that farmers who footbathed their sheep more frequently reported a higher prevalence
353 of lameness, ID and FR compared with farmers who did not footbath their sheep.
354 Amory et al. (2006) also reported the association of footbathing with a high
355 prevalence of lameness in dairy cattle. As with routine foot trimming, the association
356 between a higher prevalence of lameness, ID and FR with more frequent footbathing

357 might be a result of increased transmission of *D. nodosus* due to gathering of diseased
358 and sound sheep, poor technique that increased susceptibility of sheep or increased
359 duration of disease. Although Wassink et al. (2003, 2004) reported no significant
360 association between ID, FR and footbathing, they reported that only farmers who
361 rated their footbathing facilities as ‘excellent’ had a significantly lower prevalence of
362 FR compared with those who never footbathed their sheep or rated their facilities less
363 than excellent and, from the tables in the Wassink et al. (2003) paper, the intercept
364 term for footbathing was higher than that where farmers were not footbathing
365 (Wassink et al., 2003). The strength of evidence for the managements footbathing and
366 routine foot trimming and an increased prevalence of lameness is growing but we still
367 do not know if this is directly causal or an indirect effect; this need further testing in a
368 more robust study such a prospective cohort or an intervention study.

369 **5. Conclusions**

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

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384

385 **Conflict of interest statement**

386 The authors declare no conflict of interests.

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457 **Figure Legend:**

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

460 in 2004

461 a) Lameness b) Interdigital dermatitis c) Footrot

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463 Figure 2: Scatter plot of prevalence of interdigital dermatitis and footrot within farms

464 in 2004

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