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Article Title: A cross-sectional study of the prevalence and associated risk factors for bursitis in weaner, grower and finisher pigs from 93 commercial farms in England  
Year of publication: 2008  
Link to published version:  
<http://dx.doi.org/10.1016/j.prevetmed.2007.09.001>  
Publisher statement: None

1 **A cross sectional study of the prevalence and associated risks for bursitis in 6250**  
2 **weaner, grower and finisher pigs from 103 British pig farms**

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1 **Abstract**

2 A cross-sectional study of 103 pig farms across Britain was carried out to estimate the  
3 prevalence and associated risks of bursitis. A total of 6250 pigs aged 6 to 22 weeks  
4 were examined for presence and severity of bursitis. Details of pen construction, pen  
5 quality and farm management were recorded including floor type, presence of  
6 bedding, condition of the floor and floor materials. The crude mean prevalence of  
7 bursitis was 40.6% and increased with age. Two-level logistic regression models were  
8 developed with the outcome as the proportion of pigs affected with bursitis in a pen.  
9 Pigs kept on soil floors with straw bedding were used as the baseline. In comparison  
10 to soil floors, the associated risk for bursitis increased on deeply bedded concrete  
11 floors (OR 4.6), deep/sparse bedded concrete floors (OR 3.7), part slatted floors (OR  
12 8.0), sparsely bedded concrete floors (OR 9.0) and fully slatted floors (OR 18.7). Slip  
13 or skid marks in the dunging area (OR 1.5), pigs observed slipping during the  
14 examination of the pen (OR 1.3) and wet floors (OR 3.6) were also associated with an  
15 increased risk of bursitis. These results indicate that the associated risks for bursitis  
16 were a lack of bedding in the lying area, presence of voids and pen conditions which  
17 increased the likelihood of injury.

18

19 *Keywords:* Pig; Bursitis; Floor; Bedding; Logistic regression; Welfare

## 1 **1. Introduction**

2

3 Bursae are fluid-filled sacs that occur naturally throughout the body to decrease  
4 friction at points where muscles and tendons glide over bones (McFarland et al.,  
5 2000). Adventitious bursitis in pigs commonly arises below the hock joint on the  
6 lateroplantar, plantar and medial planes of the hind limbs and at a lower prevalence on  
7 the forelimbs. The bursal sac cavities are thought to disappear over time, leaving  
8 behind a mass of fatty connective tissue (Smith, 1993). It is undisputed that their  
9 development is associated with trauma (e.g. Smith, 1993; Lyons et al., 1995;  
10 Mouttotou et al., 1998a). Infection is not thought to play a primary role in the  
11 pathogenesis of bursitis (Marchant, 1980; Smith, 1993). Bursae are removed at the  
12 abattoir and also lead to the rejection of potential breeding stock.

13 Bursitis is a prevalent lesion amongst pigs in Britain; Mouttotou et al., (1999)  
14 reported a prevalence of 63.4% in a survey of 912 live pigs aged 8-28 weeks from 17  
15 farms. A range of values for the prevalence of bursitis have been estimated from  
16 abattoir surveys of finished pigs; 51% of 3989 pigs on 21 units in south-west England  
17 (Mouttotou et al., 1998a), 73.4% of 11811 pigs from one abattoir in Somerset (Penny  
18 & Hill, 1974), 85.4% of a cohort of 672 pigs from one farm in Somerset (Mouttotou et  
19 al., 1998b) and 87% of 14046 pigs from 5 abattoirs supplied by 146 farms in Scotland  
20 (Smith, 1993).

21 Previous evidence has indicated that bursitis is more common (Mouttotou et al., 1999)  
22 and more severe (Bäckström & Henricson, 1966) in older pigs and prevalence and  
23 severity of bursitis are associated with a hard environment that increases pressure and  
24 impact on pigs' limbs (Smith, 1993; Lyons et al., 1995; Mouttotou et al., 1998a). One

1 hypothesis is therefore that bursitis forms whilst pigs are lying (Mouttotou et al.,  
2 1998a).

3 Mouttotou et al., (1998a) reported that pigs kept on solid concrete floors with deep  
4 bedding had the lowest prevalence of bursitis, followed by pigs kept on solid concrete  
5 with sparse bedding, then those on part slatted floors and finally, fully slatted floors.  
6 Slatted floors have a smaller surface area and therefore provide less support for the  
7 weight of the pig when lying (Mouttotou et al., 1998a). In addition, pigs spend a  
8 greater proportion of time lying inactive on slatted floors compared with straw floors  
9 (Guy et al., 2002b; Scott et al., 2006) possibly because pigs on slatted floors tend to  
10 be more highly stocked. Smith (1993) reported an increased risk of bursitis with more  
11 closely stocked pigs. Slat material may also be important; metal bars have been  
12 associated with a higher prevalence of bursitis than plastic-coated bars (Smith, 1993).  
13 The presence of slats indicates a lack of bedding and Mouttotou et al., (1999)  
14 concluded from 17 farms that the use of bedding, particularly in the lying area, was  
15 associated with a reduced prevalence of bursitis by decreasing the pressure on the  
16 weight-bearing surfaces of the pig when lying.

17 Factors relating to the ease with which pigs move around their pen are also important.  
18 Steps and wet or slippery floors (Mouttotou et al., 1999), altered posture (Berner et  
19 al., 1990) and rough or damaged floors (Lahrman et al., 2003) have been associated  
20 with an increased prevalence of bursitis.

21 There are intrinsic factors associated with the susceptibility of individual pigs to  
22 bursitis. Pigmented pig breeds (either Chinese Meishan pigs or Duroc x Landrace x  
23 Hampshire cross) were less susceptible to bursitis than non-pigmented pig breeds  
24 (Landrace x Large White) reared in comparable conditions (Smith & Morgan, 1994).  
25 Pigmented pig breeds tend to have greater amounts of subcutaneous fat (Penny &

1 Hill, 1974, Smith & Morgan 1994) and thicker skin (Smith & Morgan 1994) than  
2 non-pigmented pig breeds. Pigmented pig breeds are likely to be kept outdoors on soil  
3 and therefore not exposed to voids and hard surfaces. Guy et al., (2002a) reported no  
4 additional effect of breed once floor type had been accounted for.

5 In the past, bursitis was not thought to be associated with restricted movement and  
6 reduced welfare (Bäckström & Henricson, 1966; Orsi, 1967) however, more recent  
7 research by Berner et al., (1990) indicated that bursitis may be associated with  
8 abnormal posture of the hind limbs. An association has recently been established  
9 between bursitis and abnormal locomotion in finishing pigs using the same data as  
10 this current study (Green et al., in preparation). This is one of the first indications that  
11 bursitis may have a detrimental effect on pig welfare.

12 The majority of previous work has viewed capped hock; a bursa occurring on the  
13 point of the hock (tuber calcanei), as the same lesion to bursitis in the more distal sites  
14 of the hind leg. Although it is an adventitious bursa, more recent work has indicated  
15 that risk factors for bursitis in the other localisations are different from those of  
16 capped hock (KilBride et al., submitted). Therefore, unlike previous studies (e.g.  
17 Mouttotou et al., 1998a; Mouttotou et al., 1999) the prevalence and associated risks  
18 reported here exclude capped hock. This paper presents an estimate of prevalence  
19 from 93 pig farms representative of the English pig population (Woodbine et al.,  
20 submitted) and associated risks of bursitis from 103 British pig farms. Population  
21 attributable fractions are used to estimate by how much the % of affected pigs would  
22 be reduced if a risk factor for bursitis were removed from the population.

## 1 **2. Materials and methods**

2

### 3 *2.1. Study population*

4

#### 5 *2.1.1. Farm selection*

6 A total of 549 pig farms from England and Wales were randomly selected from the  
7 NPA (National Pig Association) database which holds data on approximately 85% of  
8 the national pig herd. The criteria for selection from this database were breeder to  
9 finisher farms with more than 100 breeding sows. Of the 549 pig farmers contacted,  
10 101 agreed to take part, of which 7 were used in a pilot study to test the scoring  
11 systems and to train observers. The remaining 94 farms were used in the main study.  
12 A further 9 farms were non-randomly selected for participation; 5 farms in Scotland  
13 were recruited by QMS (Quality Meat Scotland) and 4 farms in England were  
14 recruited via their veterinarian.

15

#### 16 *2.1.2. Pig selection*

17 On each farm, one pen containing pigs of each of the following ages was randomly  
18 selected; 6 and 8 weeks (weaners), 10, 12 and 14 weeks (growers) and 18 and 22  
19 weeks (finishers). When the sample ages were not available the nearest age was  
20 selected. If there were less than 10 pigs in the pen, all animals were examined, if there  
21 were more, 10 pigs were randomly selected.

22

### 23 *2.2. Examination of pigs*

24

1 All four limbs were examined for evidence of bursitis while the pig moved freely  
2 around the pen. Severity of individual bursae was scored 0-3 as follows; 0 = no visible  
3 swelling, 1 = <25% swelling, 2 = 25-50% swelling and 3 = >50% swelling in  
4 comparison with the size of the carpal/tarsal joint. This was adapted by the scoring  
5 system developed by Mouttotou *et al.*, (1998a). Mouttotou *et al.*, used absolute size of  
6 bursa to measure severity, but as this does not take account of the size of the pig, a  
7 relative measure was devised. When there was more than one bursa on the same limb,  
8 only the most severe was scored. Recordings were made on the number of pigs in the  
9 pen, how long pigs had been in the pen and whether pigs were seen slipping on the  
10 floor whilst the pen was observed. Eight observers scored the pigs.

11

### 12 2.3. Examination of the environment

13

14 Data were collected on the condition and construction of the pen. The following  
15 construction data were recorded; pen dimensions, pen design (width restrictions and  
16 steps), floor type (slatted, part slatted or solid), floor material (concrete, metal or  
17 plastic), slat dimensions (slat and void width and length) and slat characteristics (slat  
18 surface, slat profile, and void shape). In addition, observations were made on the  
19 condition of the floor and bedding (depth, cleanliness and dryness). Bedding depth  
20 was recorded as either deep (the whole pen was covered with bedding and none of the  
21 floor was visible), deep/sparse (only part of the pen was deeply bedded, the rest was  
22 either sparse or completely bare) or sparse (there was only a thin layer of bedding and  
23 the floor was clearly visible). The condition of the floor was scored as  
24 presence/absence of wetness, wear, sharp edges, damage, wet slurry, dry slurry, fresh  
25 dung and slip marks in four key pen areas. These areas were the lying and dunging



1 areas and under the feeder and drinker; 11 observers recorded data on the pen  
2 characteristics.

3

#### 4 *2.4. Interview with farmer*

5

6 A detailed interview was conducted with each farmer at the time of the farm visit.  
7 Information was obtained on herd size and breed lines. Breed was used to create a  
8 binary, farm-level variable for pigmented/non pigmented pig breeds. Farms were  
9 classified as using pigmented pig breeds if there was Hampshire, Duroc or Meishan in  
10 their breed lines.

11

#### 12 *2.5. Data analysis*

13

##### 14 *2.5.1. Data entry checking*

15 Data were entered into Microsoft Access 2003 databases by research assistants and a  
16 professional data entry company. The databases were checked for errors and outliers  
17 and any obvious incorrect codes were re-checked against the raw data.

18 In order to calculate the prevalence of bursitis, all pigs from non-randomly selected  
19 farms and the single Welsh farm were excluded to provide an estimate of the  
20 prevalence in England (n = 93). Prevalence was calculated as:

21

22

23

24

$$\frac{\text{No. of pigs affected with bursitis}}{\text{No. of pigs examined on randomly selected farms}}$$

##### 25 *2.5.2. Bursitis prevalence*

26 A pig was defined as affected with bursitis if at least one lesion greater than score 0  
27 was present on at least one of the four limbs. The sample of pigs examined in each

1 pen was used to calculate the outcome variable, which was estimate of proportion of  
2 pigs affected within each pen, as follows;

3

$$\frac{\text{No. of pigs with bursitis per pen sample}}{\text{No. of pigs examined per pen (max.10)}}$$

6

### 7 *2.5.3. Logistic regression*

8 The outcome was proportional data at pen level as there were no predictor variables  
9 measured at pig level. Pens within farms had a lower variance than equivalent pens  
10 within different farms. To account for the clustering of both pigs within pens and pens  
11 nested within farms, a 2-level binomial logistic regression model was used. A  
12 binomial model was used instead of a general linear model as severity score was not a  
13 continuous outcome with a normal distribution. MLwiN version 2.01 (Rasbash et al.,  
14 1999) was used for all multilevel analysis. All non-randomly selected farms were  
15 included (n=103).

16 Many of the pen variables were correlated with floor type e.g. the presence of width  
17 restrictions and steps were associated with part slatted floors. It was therefore  
18 necessary to analyse sections of the data separately. As the presence of bedding and  
19 slats were mutually exclusive, the floor data were split into two groups; slatted or part  
20 slatted (and consequently non-bedded) floors (model A) and solid floors with bedding  
21 (model B). Pen design and pen construction variables were investigated with the full  
22 data set (model C).

23 Since presence of bedding was highly correlated with solid floors, a 6-level variable  
24 was created that combined floor type and bedding depth. Solid floored pens were  
25 divided into soil floored pens (outdoor), deeply bedded concrete floors, deep/sparse  
26 bedded concrete floors and concrete floors with sparse or no bedding. All non-soil

1 solid floors were made from concrete. The majority of soil floors were deeply bedded  
 2 and therefore soil floors were not split by bedding depth. Slatted floors were  
 3 categorised into part slatted or fully slatted.

4 The prevalence of bursitis increased with age and age was a strong confounder with  
 5 many pen construction variables e.g. concrete slats were mainly used for finishing  
 6 pigs. Age was therefore included as a continuous variable throughout the initial  
 7 (bivariable) investigations. Herd size and the number of pigs in pens were added to  
 8 the models to check for any confounding.

9 All models were built using the same process; all continuous variables were checked  
 10 for linearity and categorised into 5 groups if non-linear. Variables that were  
 11 significant at  $p < 0.2$  in the bivariable analysis were taken forward to the multivariable  
 12 stage (Dohoo *et al.*, 2003 p.321-322). Models A, B and C were initially built for each  
 13 age group separately (weaners, growers and finishers) to establish any variables  
 14 important by age.

15

16 When a pair of variables were correlated the most biologically plausible variable was  
 17 selected. Both forward and backward elimination were used (Dohoo *et al.*, 2003  
 18 p.327-328) and variables were retained when they improved the model fit by  $p < 0.05$ .

19 Finally all remaining variables were re-introduced in the model to check for residuals  
 20 confounding (Cox & Wermuth, 1996). The model took the form:

$$21 \quad Y_{ij} = \beta_0 + \sum \beta_n X_{ij} + \sum \gamma_n X_j + v_0_j + u_{0ij}$$

22 Where  $\beta_0$  is the intercept,  $\beta$  = coefficients for  $X_{ij}$ ,  $X_{ij}$  = variables varying between  
 23 pens,  $\gamma$  = coefficients for  $X_j$ ,  $X_j$  = variables varying between farms,  $v_0_j$  = residual error  
 24 between farms,  $u_{0ij}$  = residual error of the model.

1 The fit of model A was checked using the Hosmer Lemeshow goodness-of-fit statistic  
2 (Dohoo *et al.*, 2003 p360-361).#

3

#### 4 *2.5.4. Population attributable fractions*

5 Population attributable fractions were calculated (Dohoo *et al.*, 2003 p.128) to  
6 estimate the proportion of affected pigs with bursitis that would be reduced if a  
7 particular risk factor was removed and the pigs were housed instead on the baseline  
8 with the lowest prevalence of bursitis. Population attributable fractions (expressed as  
9 a percentage) were calculated for all variables significant in the final model, either  
10 within age groups or for the whole dataset, depending on whether age was an  
11 important confounder of that variable. The calculation was as follows (Dohoo *et al.*,  
12 2003 p. 128-130):

$$13 \quad AF_p = [RD * p(E+) / p(D+)] * 100$$

14 Where  $AF_p$  is the population attributable fraction (expressed as a percentage), RD is  
15 the risk of bursitis in the exposed group minus the risk of bursitis in the unexposed  
16 group,  $p(E+)$  is the proportion of pigs on each floor type and  $p(D+)$  is the proportion  
17 of pigs with bursitis on each floor type.

18

#### 19 *2.6. Pathology*

20 Nine pigs of 9 to 16 weeks were selected from two farms (five from a farm with fully  
21 solid concrete floors with bedding and four from a farm with fully slatted concrete  
22 floors). Two bursitis lesions from each severity score and two controls were collected  
23 from each farm. Gross and histo- pathological examinations were carried out on each  
24 lesion.

### 1 **3. Results**

2

#### 3 *3.1. Summary of the data*

4

5 6250 post-weaning pigs from 646 pens on 103 farms in Britain were examined  
6 between 23<sup>rd</sup> September 2003 and 2<sup>nd</sup> August 2004. Of these farms, 21 (20.4%) reared  
7 at least some stages of pigs outdoors. There were 58 pens with a soil floor (9.0%), 249  
8 pens (38.5%) with a solid floor, 162 pens (25.1%) that were part slatted and 175  
9 (27.1%) were fully slatted. 283 (43.8%) solid pens had bedding. A median of 64 pigs  
10 were sampled from each herd (range 19-70). There was no difference between  
11 observers for the mean bursitis score by pen type. Three farms had less than 100 sows  
12 due to changes in circumstance since publication of the NPA database. The median  
13 herd size was 317 breeding sows (range 20-2300) and the median group size (number  
14 of pigs in the pen) was 30 (range 5-400). The sample of farms was representative of  
15 Britain in both farm size and distribution (Woodbine et al., in press) and the  
16 proportion of outdoor and indoor pigs and herds.

17

#### 18 *3.2. Prevalence of bursitis*

19 The overall prevalence of pigs affected with bursitis in randomly selected farms in  
20 England was 40.6% of 5561 pigs, ranging from 0-92.5% per farm and 0-100% per  
21 pen. Bursitis increased with age (OR 1.1) both in prevalence and severity (Figure 1),  
22 reaching a maximum prevalence of 59.3% in 732 pigs at 22 weeks of age. 50.0% of  
23 all pigs with bursitis had a maximum severity score of 1, 36.4% had a score of 2 and  
24 13.5% had a score of 3 on any one leg.

25

### 1 3.3. Associated risks for bursitis

2 Sub-models were created to examine the risk factors within slatted pens only (model  
3 A; Table 1), and bedded pens only (model B; Table 2) before creating a model which  
4 encompassed all pens (model C; Table 3). Within model C, using soil floors as the  
5 baseline for comparison, there was an increased prevalence of bursitis associated with  
6 all other floor types; deeply bedded concrete floors (OR 4.6), deep/sparse bedded  
7 concrete floors (OR 3.7), sparsely bedded concrete floors (OR 9.0), part slatted floors  
8 (OR 8.0) and fully slatted floors (OR 18.7) (Table 3). An average of 61.5% of the pigs  
9 on fully slatted floors were affected with bursitis compared with 4.4% on soil floors  
10 (Figure 2). Estimates of population attributable fractions indicated that housing pigs  
11 on soil floors instead of fully slatted floors would result in between 32.1% and 45.7%  
12 reduction in the prevalence of bursitis depending on age (Table 5). When compared  
13 with a baseline of deeply bedded concrete floors there was no significant difference in  
14 the risk of bursitis in pens with deep/sparse bedded concrete floors. However there  
15 was a significant increase in risk associated with sparsely bedded concrete floors (OR  
16 1.9). In addition, fully slatted floors (OR 2.3) were associated with a greater risk of  
17 bursitis than part slatted floors.

18 In pens containing slats (model A), there was a significant increase in bursitis  
19 prevalence associated with metal slats (OR 1.7) in comparison with concrete slats.  
20 However, there was no significant difference between plastic slats and either metal or  
21 concrete slats (Table 1). Slat material was correlated with other slat characteristics e.g.  
22 concrete slats tend to have the smallest void to slat ratio (18.4% void), the largest void  
23 area (203cm<sup>2</sup>), a flat slat profile and sharp edges (Table 4).

24 When the data were grouped by age, the same association was seen between bursitis  
25 and floor/bedding type within the growers and finisher age groups. This was not seen

1 for weaners, where soil floors were not associated with a significantly lower  
2 prevalence of bursitis compared with solid concrete floors with deep or deep/sparse  
3 bedding.

4 Additional factors associated with an increased risk of bursitis were; pigs observed  
5 slipping during the visit (OR 1.3), slip or skid marks in the dunging area (OR 1.5),  
6 wear/visible aggregate in the pen (OR 1.3) and food on the floor of the lying area (OR  
7 1.6) (Table 3). On deeply bedded and soil floors, pigs were rarely observed slipping  
8 (12.2% and 14.0% of pens respectively), compared with sparsely bedded (53.7%),  
9 part slatted (56.1%) and fully slatted floors (51.9%). In farms where wet food was  
10 provided, the average proportion of slip and skid marks rose by 11.6% in weaners,  
11 15.6% in growers and by 27.4% in finishers. Within the weaner age group, the only  
12 significant factors associated with bursitis were floor type and bedding; pen  
13 conditions at this early age were not significantly associated with bursitis.

14 Within slatted pens (model A), wear/visible aggregate under the feeder (OR 1.7) was  
15 associated with a greater prevalence of bursitis (Table 1). Within solid floor pens with  
16 bedding (model B), pens where there was fresh dung under the drinker were  
17 associated with a reduced risk of bursitis (OR 0.6) as were pigmented pig breeds (OR  
18 0.4). Pigmented pig breeds were associated with a reduced risk of bursitis for both  
19 growers and finishers, but there was no effect within the weaner age group. 59% of  
20 outdoor pens contained pigmented pig breeds. There was a greater risk of bursitis in  
21 bedded pens when the floor was wet (OR 3.6) or damaged (OR 1.6) (Table 2). Wet  
22 floors were most common in sparsely bedded pens (100% of pens) and least common  
23 in soil pens (77% of pens).

24 Herd size and group size (number of pigs in the pen), stocking density and time in the  
25 pen had no significant effects in the models and therefore did not affect the accuracy

1 of the prevalence estimate. The Hosmer Lemeshow statistic was non-significant,  
2 indicating a good fit between the model and the data ( $\chi^2 = 0.904$ ,  $p > 0.5$ ).

3

#### 4 *3.4. Pathology*

5 On examination of the lesions, 12 had a lumen and remnants of slight older  
6 haemorrhage. Some had scattered inflammatory cells in the bursal wall (Figures 3 and  
7 4). Two (clinical score 3) had no bursal sac, instead there were large solid areas of  
8 connective tissue (Figure 5). When examining the live pigs there was no discernable  
9 difference on palpation of the swellings with and without bursal sacs. There was no  
10 indication of a difference in the pathological severity of the lesions by clinical size.



#### 1 **4. Discussion**

2

3 The mean prevalence of bursitis from the random sample of units was 40.6%; this is  
4 possibly the most accurate prevalence estimate to date for weaner-finisher pigs on  
5 commercial farms in England. The 93 randomly selected farms were representative of  
6 the overall population of pig farms in England in both size and geographical  
7 distribution (Woodbine et al., in press). This allowed population attributable fractions  
8 to be calculated to estimate the effect of the associated risks in the population,  
9 assuming that the associated risks were causal. A prevalence of 63.4% (which  
10 included capped hock) was recorded in the only other comparable research on bursitis  
11 in live pigs (Moultotou et al., 1999). However, the capped hock prevalence was only  
12 0.7% and therefore unlikely to explain this difference in bursitis prevalence. The work  
13 by Moultotou et al., (1999) involved 17 farms in the south-west of England all serving  
14 1 abattoir and was not representative of pigs in England in geographical distribution.  
15 Only the grower and finisher age groups were examined which is likely to account for  
16 the greater prevalence.

17 However, there may have been a sampling bias in this study towards farms with  
18 higher health and welfare standards as the sampling frame was farms belonging to an  
19 assurance scheme and participation in the study was voluntary. Any bias should be  
20 minimal due to the high proportion of all farms belonging to the NPA. Although the  
21 prevalence may be accurate for commercial farms with over 100 sows, the prevalence  
22 on smaller farms may differ.

23 The associated risks for bursitis can be considered in terms of floor type and floor  
24 condition. The relationship between floor type and bedding with the risk of bursitis  
25 indicated that slatted floors and floors with little or no bedding were both associated

1 with an increased prevalence of bursitis. Whether deep bedding is throughout the pen  
2 or just in the lying area had no significant effect on the associated risk of bursitis,  
3 whereas having sparse bedding in the lying area was associated with a significantly  
4 greater risk of bursitis, implying that these lesions may be a response to lying rather  
5 than walking on a hard surface. Soil floors may provide a softer lying surface  
6 compared with concrete floors over and above the effect of deep bedding. However,  
7 there may have been some confounding between pigs kept outdoors on soil and pigs  
8 with pigmented skin. There was a protective effect of pigmented pig breeds observed  
9 within bedded pens (model B), possibly indicating a small protective effect from the  
10 cushioning provided by greater amounts of fat and thicker skin compared with non-  
11 pigmented in outdoor conditions, but this effect was not consistent across all floor  
12 types or all ages. However, Guy et al., (2002a) conducted a thorough investigation of  
13 breed and reported that it had little effect on bursitis prevalence.

14 Fully slatted floors (and therefore a slatted lying area) were associated with a greater  
15 risk of bursitis than part slatted floors (and therefore a solid lying area) indicating that  
16 lying on slats was associated with a risk of bursitis over and above that of lying on a  
17 hard floor. Slatted floors provide a smaller surface area on which to distribute weight  
18 and therefore put additional pressure on the parts of the pig in contact with the floor. It  
19 may be for this reason that concrete slats are associated with a lower prevalence of  
20 bursitis compared with metal. Concrete slats also had the smallest void to slat ratio.  
21 However, slat material dictates the majority of other slat properties (Table 4) and so it  
22 is possible that it was not surface area, but one of the other properties that were  
23 associated with bursitis. Older pigs are more likely to be kept on slats which may  
24 account for the increase in prevalence with age, in conjunction with a greater body  
25 weight exerting additional pressure on the limbs and a greater proportion of time spent

1 lying (Ekkel et al., 2003). The lack of difference within the weaner age group between  
2 soil floors with bedding and deeply bedded concrete floors may indicate that,  
3 providing the bedding is deep, the surface underneath makes little difference due to  
4 the lower body weight of weaner pigs.

5 A positive association between the number of pigs seen slipping and the presence of  
6 slip and skid marks with the prevalence of bursitis indicated an association between  
7 bursitis and injury. An increased risk of bursitis associated with slip and skid marks in  
8 the dunging areas indicated that slipping and injury may be occurring in areas likely  
9 to be slatted and where pigs are walking rather than when getting up or lying down.  
10 The fact that pigs were less commonly seen slipping on deep bedding may indicate  
11 that bedding adds some degree of friction to a surface. Pigs were also more frequently  
12 observed slipping on concrete slats compared with metal or plastic – however pigs  
13 observed slipping during the visit were adjusted for in model A and so it is possible  
14 that the extra support provided by a larger slat surface area, and a smaller total  
15 proportion of void area outweighs any negative effect of slipperiness on concrete  
16 slats. Wet solid floors may prove hazardous as the lack of drainage may make them  
17 particularly slippery. Feed on the floor, particularly liquid feed, may also increase the  
18 difficulty of walking on a surface. Factors associated with damage to the floor such as  
19 a worn floor under the drinker or damage in bedded pens may contribute to the  
20 likelihood of injury or may be associated with an increase in bursitis as a direct result  
21 of lying on these surfaces. It may also be possible that these uneven surfaces cause  
22 damage to feet which leads to a greater proportion of time spent lying (Moultotou *et*  
23 *al.*, 1998a). The mechanism by which fresh dung under the drinker was associated  
24 with reduced prevalence of bursitis is unclear and it may be that this variable was  
25 correlated with another variable that was not measured in this study.

1 Previous research has reported that stocking density (Smith, 1993) and a step of >3cm  
2 between the solid and slatted areas (Mouttotou et al., 1999) are associated with an  
3 increased risk of bursitis. However, neither of these variables were significant in this  
4 study. It may be that there is no longer as much variation in stocking density that was  
5 observed in 1993 and therefore any effect on prevalence may be difficult to detect. A  
6 step in the pen may have been acting as a proxy for floor type as steps are most  
7 common on part slatted floors; making the actual effect of a step hard to distinguish.

8 Some variables in the models (e.g. pigs observed slipping during the examination of  
9 the pen) had odds ratios with confidence intervals touching unity. Although this  
10 means that we can not be so certain about their effect, the fact that these variables  
11 tended to be the less robust ones and still show significance was remarkable and  
12 meant that the variables were included in the models.

13 Two principal hypotheses emerged from this paper on the possible causes of bursitis.  
14 One is that bursitis occurs whilst lying; as a response to floors without bedding and  
15 floors with a reduced surface area to support the weight of the pig. The second is that  
16 bursitis is a result of injuries from knock and bumps incurred whilst moving around  
17 the pen. A combination of both hypotheses is possible.

18 Whether bursae arise as a protective response to pressure and/or impact, or have a  
19 negative effect on pig welfare is not clear (e.g. Bäckström & Henricson, 1966; Orsi,  
20 1967). The association between bursitis and gait score (Green et al., in preparation)  
21 indicates that these swellings may be associated with discomfort or may be a correlate  
22 for other factors causing poor gait (Mouttotou et al., 1998a). The position (in an area  
23 where there is no restriction on the bursa size) and nature of the bursae suggest that  
24 they may not be particularly painful. This indicates that the bursal lesions were  
25 unlikely to have been associated with poor gait in this study. Regardless of their

1 function and level of discomfort caused, bursae are not a normal part of the anatomy  
2 and cause a loss to the pig industry from the removal of the lesions at slaughter and  
3 the rejection of potential breeding animals. Cohort and intervention studies  
4 investigating the development of these lesions would be of considerable use to  
5 investigate aetiology and pathogenesis of bursae.

6

## 7 **5. Conclusion**

8 The current estimate for bursitis in England was 40.6%. This highly prevalent lesion  
9 may have important welfare consequences. When compared with the baseline of soil  
10 floors with bedding, concrete floors with deep bedding and floors where no deep  
11 bedding was available in the lying area were associated with an increasingly greater  
12 risk of bursitis. A fully slatted lying area was associated with a greater risk of bursitis  
13 than a solid lying area. Factors which may result in the pig slipping and injuring itself  
14 were also associated with a greater risk of bursitis. Although these risk factors have  
15 been alluded to in past research, this is the first study to find so many similar factors  
16 important. Population attributable fraction calculations indicated the importance of  
17 some of these factors in the development of bursitis.

1 **Acknowledgements**

2 We thank the farmers and veterinarians who kindly agreed to participate in the  
3 project. The field technicians and research staff who helped in collecting the data;  
4 Jane Slevin, Kerry Woodbine, Megan Turner, Emma Novell, Charlotte Boss, Fiona  
5 Boyd, Martin Crockett, Maureen Horne, Lucy Wilson and Bart van den Borne.  
6 This project was funded by Department for Environment, Food and Rural Affairs  
7 project number AW1021.

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## 1 Table 1

2 Model A: 2-level binomial logistic regression model for the associated risks for  
 3 bursitis with the outcome of proportion of pigs per pen with bursitis; where pens have  
 4 either part slatted or fully slatted floors

	n	%	b	SE	OR	CI	P
Constant			-2.99	0.37			
<i>Age (weeks)</i>	5-23		0.18	0.02	1.2	1.1-1.2	<0.001
<i>Floor type</i>							
Part slatted <sup>a</sup>	142	46					
Fully slatted	157	62	0.77	0.15	2.2	1.6-2.9	<0.001
<i>Slatted floor material</i>							
Concrete <sup>a</sup>	117	68					
Plastic	121	48	0.31	0.22	1.4	0.9-2.1	
Metal	61	42	0.55	0.24	1.7	1.1-2.8	<0.05
<i>Pig seen slipping</i>							
No <sup>a</sup>	134	49					
Yes	165	59	0.30	0.14	1.4	1.0-1.8	<0.05
<i>Wear or visible aggregate under feeder</i>							
No <sup>a</sup>	258	52					
Yes	41	69	0.51	0.20	1.7	1.1-2.5	<0.05

5

6 <sup>a</sup>Reference category

7 Number of pens in each exposure (n), percentage of pigs affected (%), coefficients

8 (b), standard errors (SE), risk ratios (OR) and 95% confidence intervals (CI)

1 Table 2

2 Model B: 2-level binomial logistic regression model for the associated risks for

3 bursitis with the outcome of proportion of pigs per pen with bursitis; where pens have

4 fully solid, bedded floors

	N	%	b	SE	OR	CI	P
Constant			-2.39	0.41			
Age (weeks)	5-22		0.64	0.02	1.9	1.8-2.0	<0.001
<i>Floor/Bedding</i>							
Soil <sup>a</sup>	39	6					
Solid concrete / Deep bedding	77	26	1.51	0.40	4.5	2.0-10.1	<0.001
Solid concrete / Deep/sparse bedding	64	29	1.52	0.39	4.6	2.1-10.0	<0.001
Solid concrete / Sparse bedding	38	51	2.26	0.42	9.6	4.1-22.2	<0.001
<i>Pigmented breed</i>							
No <sup>a</sup>	106	39					
Yes	112	17	-0.87	0.27	0.4	0.2-0.7	<0.05
<i>Fresh dung under drinker</i>							
No <sup>a</sup>	146	29	0.00	1.00			
Yes	72	24	-0.46	0.18	0.6	0.4-0.9	<0.05
<i>Wetness on the floor of the pen</i>							
No <sup>a</sup>	25	10	0.00	1.00			
Yes	193	30	1.27	0.32	3.6	1.9-6.8	<0.001
<i>Damage on the floor of the pen</i>							
No <sup>a</sup>	185	27	0.00	1.00			
Yes	33	32	0.54	0.21	1.6	1.0-2.4	<0.05

5

6 <sup>a</sup>Reference category

7 Number of pens in each exposure (n), percentage of pigs affected (%), coefficients (b), standard errors

8 (SE), risk ratios (OR) and 95% confidence intervals (CI)

## 1 Table 3

2 Model C: 2-level binomial logistic regression model for the associated risks for

3 bursitis with the outcome of proportion of pigs per pen with bursitis for all pens

	N	%	b	SE	OR	CI	P
Constant			-2.54	0.21			
Age (weeks)	5-23		0.11	0.01	1.1	1.1-1.1	<0.01
<i>Floor/Bedding</i>							
Soil <sup>a</sup>	45	6					
Solid concrete / Deep bedding	77	24	1.53	0.34	4.6	2.3-9.1	<0.01
Solid concrete / Deep/sparse bedding	67	31	1.31	0.34	3.7	1.9-7.3	<0.01
Solid concrete / Sparse bedding	45	52	2.20	0.36	9.0	4.4-18.5	<0.01
Part slatted / No bedding	149	47	2.08	0.33	8.0	4.1-15.5	<0.01
Fully slatted	144	64	2.93	0.32	18.7	9.9-35.5	<0.01
<i>Pig seen slipping</i>							
No <sup>a</sup>	313	34					
Yes	214	55	0.24	0.12	1.3	1.0-1.6	<0.05
<i>Food on the floor in the lying area</i>							
No <sup>a</sup>	496	42					
Yes	31	60	0.47	0.22	1.6	1.0-2.5	<0.05
<i>Slip/skid mark on floor in dunging area</i>							
No <sup>a</sup>	433	39					
Yes	94	59	0.42	0.15	1.5	1.1-2.1	<0.05
<i>Wear or visible aggregate on pen floor</i>							
No <sup>a</sup>	327	39					
Yes	200	50	0.27	0.11	1.3	1.1-1.6	<0.05

4

5 <sup>a</sup>Reference category

6 Number of pens in each exposure (n), percentage of pigs affected (%), coefficients (b), standard errors

7 (SE), risk ratios (OR) and 95% confidence intervals (CI)

- 1 Table 4
- 2 Properties of the three different slat materials

	Concrete slats	Plastic slats	Metal slats
N	132	128	64
Void size cm <sup>2</sup> :	203	8.5	8.4
median (Q1-Q3)	(147, 264)	(5.8, 9.1)	(6.9, 14.3)
Void width cm:	2	1	1
median (Q1-Q3)	(2-2.28)	(1-1.1)	(1-1.4)
Void length cm:	104	8	7.5
median (Q1-Q3)	(77.6-120)	(6-9)	(7-8.5)
Percentage void in the slatted area:	18.4	41.1	55.6
median (Q1-Q3)	(17.0, 21.4)	(34.5, 44.4)	(46.6, 68.8)
Flat slat profile (%)	81.0	82.1	42.1
Sharp slat edge (%)	51.8	9.9	3.6
Pigs seen slipping (%)	58.3	49.2	42.2

3

## 1 Table 5

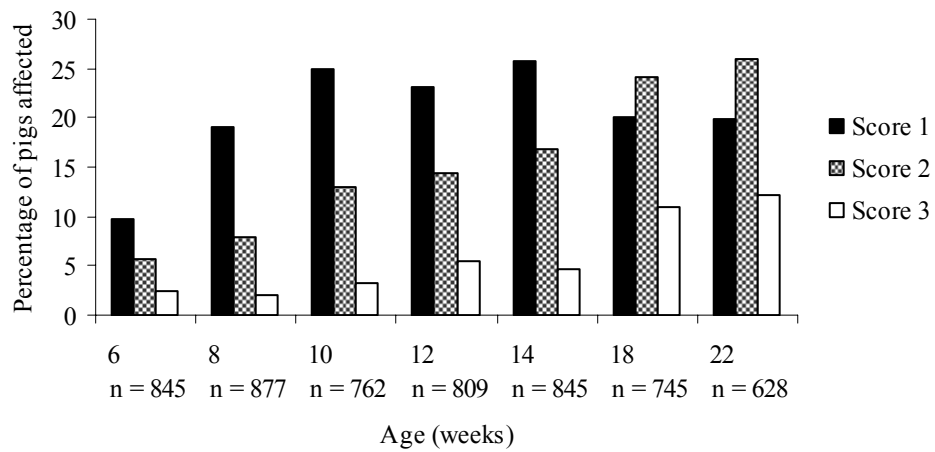
2 Population attributable fractions expressed as percentages for model C for all  
 3 randomly selected farms in England. Values give the proportion by which the number  
 4 of affected pigs would be reduced by if the variable were removed from the  
 5 population and the pigs housed on the reference category condition

Floor/Bedding	Weaners	Growers	Finishers	All ages
Soil <sup>a</sup>				-
Solid concrete / Deep bedding	2.2	9.9	5.8	-
Solid concrete / Deep/sparse bedding	1.2	8.1	12.6	-
Solid concrete / Sparse bedding	7.8	9.0	16.2	-
Part slatted / No bedding	31.1	26.1	25.3	-
Fully Slatted	45.7	32.1	40.1	-
Pigs seen slipping: No <sup>a</sup>	-	-	-	
Yes	-	-	-	18.0
Food on the floor of the lying area: No <sup>a</sup>	-	-	-	
Yes	-	-	-	26.0
Slip/skid marks on floor in dunging area: No <sup>a</sup>	-	-	-	
Yes	-	-	-	71.5
Wear or visible aggregate on pen floor: No <sup>a</sup>	-	-	-	
Yes	-	-	-	13.0

6

7 <sup>a</sup>Reference category

1



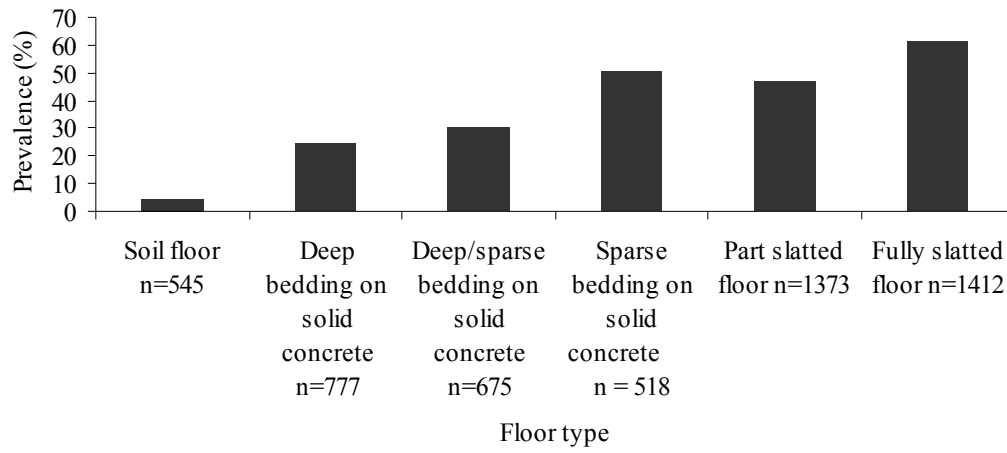
2

3 Fig. 1.

4 Percentage of pigs at each age group affected with bursitis of different severities on  
5 randomly selected farms

6 93 farms 579 pens 5511 pigs

1



2

3 Fig. 2.

4 Proportion of pigs in the random sample with bursitis by floor type

5 93 farms 576 pens 5300 pigs



1



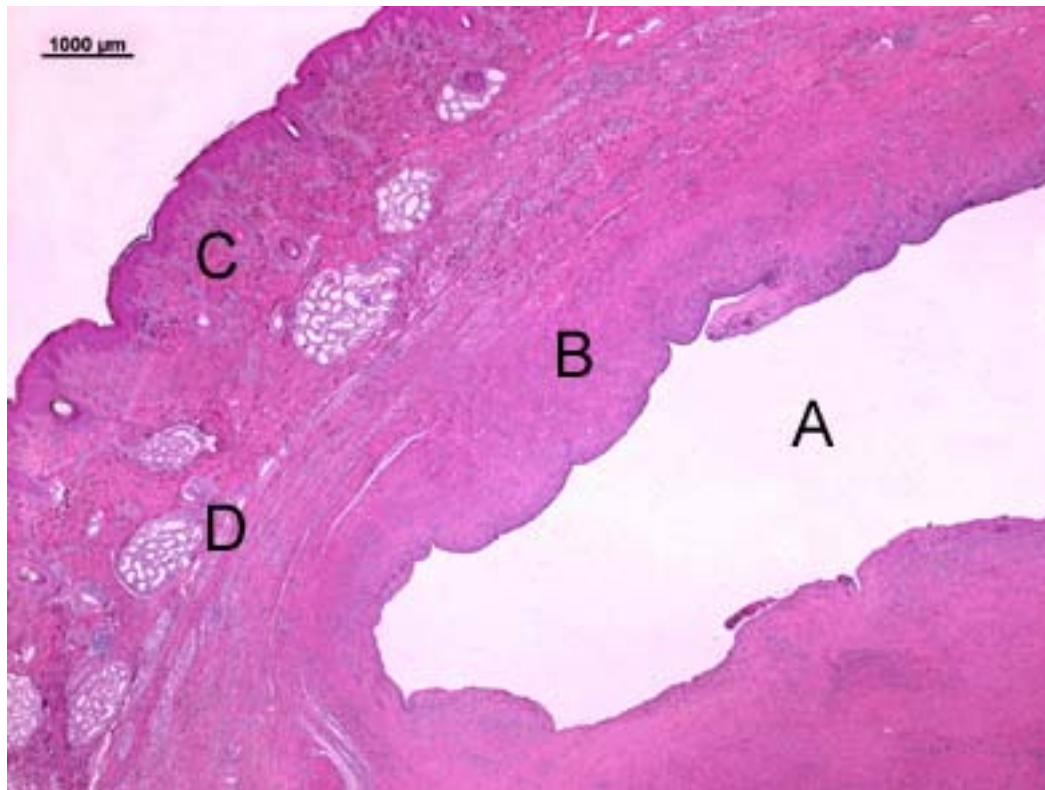
2

3 Fig. 3.

4 Bursal swelling with bursal sac (B) containing watery, blood tinged fluid (clinical

5 score 1)

1

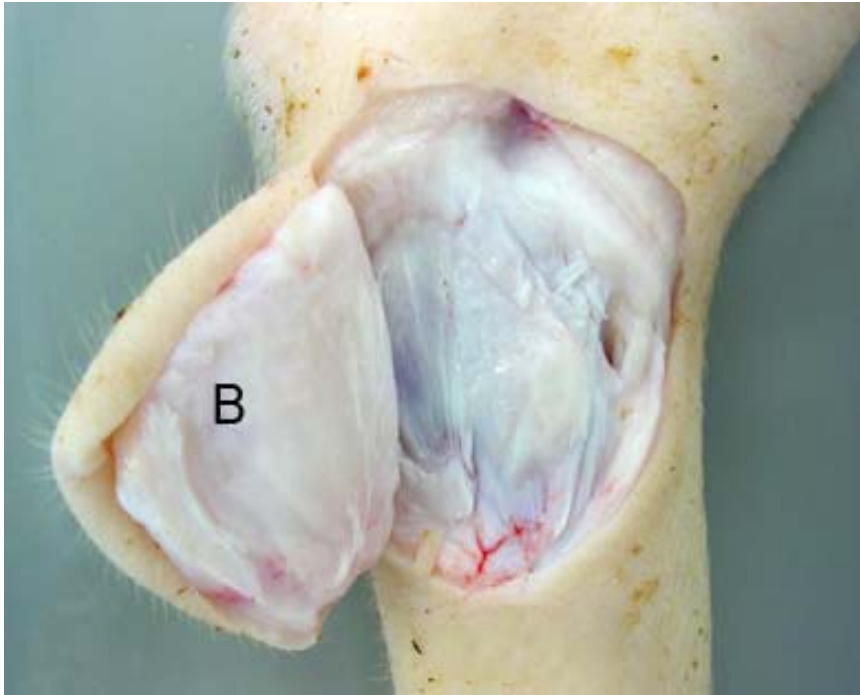


2

3 Fig. 4.

4 Overview of a tarsal bursa showing the lumen (A) and its capsule of dense connective

5 tissue (B) under the haired skin (C) which also contains numerous sweat glands (D)



1

2 Fig. 5.

3 Bursal swelling consisting of solid connective tissue (A); there was no bursal sac

4 (clinical score 3)