An epidemiological study of foot, limb and body lesions and lameness in pigs

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Declaration

I declare, that apart from advice and assistance acknowledged here, the work reported in this thesis is my own and has not been submitted for any other degree.

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The following papers have been included in conference proceedings:

KilBride, AL, Gillman CE and Green LE. Prevalence of foot lesions, limb lesions and abnormal locomotion in pigs on commercial farms in Britain and risks associated with flooring. The Pig Journal, 61. 2008. In press. Presented at Pig Veterinary Society Meeting, Dublin, 2007.

KilBride AL, Gillman CE and Green LE. Prevalence of foot and limb injuries in preweaning piglets and risks associated with indoor flooring: a cross-sectional study. Proceedings of the 11th Symposium of the International Society for Veterinary Epidemiology and Economics, ISVEE 11, 494. Presented in Cairns, Australia: 2006.

Summary

A cross sectional study of 103 indoor and outdoor British pig farms was carried out in 2003-2004. Over 12,000 pigs aged from 3 days up to multiparious breeding sows were examined. Prevalence of foot, limb and body lesions and lameness was recorded using clear case definitions. Detailed data were also collected on the pen or paddock that the pigs were housed in with particular reference to the floor design, material and condition. Associations between prevalence of disease and the environment the pig was housed in were analysed using multilevel regression models. Post-mortem examination of a small sample of foot and limb lesions was carried out to better understand the pathology.

There was a lower prevalence of body and limb lesions in pigs of all ages, and foot lesions in preweaning piglets, housed outdoors compared with indoors. However, there was little difference in the prevalence of foot lesions and lameness in gilts and pregnant sows kept indoors compared with outdoors.

In most pigs housed indoors, there was a trend for an increased risk of limb and body lesions and lameness in pigs housed on hard and slatted floors compared with solid concrete floors with bedding. Although, in contrast to this the prevalence of wounds on the limbs in piglets was lower on slatted floors compared with solid concrete floors. The associations between foot lesions and indoor floor type varied with the age of the pig and the type of lesion. In piglets, sole bruising was associated with housing on slatted floors while sole erosion was associated with housing on solid concrete floors without bedding. In gilts and sows, heel flaps were associated with housing on slatted floors while toe erosion was associated with solid floors with deep bedding.

In conclusion, this study has provided the most accurate estimates of the prevalence of foot, limb, body lesions and lameness in the English pig herd to date and generated useful hypotheses regarding the aetiology of these lesions. To further understand this topic cohort and intervention studies are now needed.

List of Abbreviations

OR	Odds ratio
CI	Confidence interval
IQR	Interquartile range
SE	Standard error
Var.	Variance
ABP	Assured British Pigs
DEFRA	Department for Environment, Food and Rural Affairs
PMWS	Post weaning multisystemic wasting syndrome

Chapter 1

General introduction

1.1 Background

Pig meat is the most popular meat protein consumed by humans worldwide and production continues to increase as demand for pig meat grows from newly industrialised countries such as China (Anon, 2007). The domestic pig (*Sus scrofa)* originates from Eurasian wild boars, which are still widespread in mainland Europe and parts of Africa (Giuffra *et al.*, 2000). The habitat of wild boars is woodland, with a preference for deciduous forest (Fonseca, 2008). Family groups forage over a wide area, travelling, on average, 7km a day over a range of approximately 100ha (Lemel *et al.*, 2003). Breed lines of pigs used in commercial production have been selectively bred to maximise reproductive productivity and production of lean tissue. Despite the considerable changes this has brought to the phenotype of *Sus scrofa,* observations of domestic pigs housed in a semi-natural environment (Stolba and Wood-gush, 1989), indicated that modern genotypes of pigs, given the opportunity, exhibit a wide complex range of foraging and social behaviour, almost identical to wild boar.

1.2 Flooring on commercial pig farms

Housing of pigs reared for meat has revolutionised over the last 50 years. Hardwear and automation have been introduced that have reduced labour requirements and costs to maximise production. Confinement and stocking densities have increased and environments have become more barren (Fraser, 2005). Modifications in flooring have been a key component of this change. The use of slatted floors has become increasingly widespread in commercial pig production. Slatted floors allow excreta to pass through the voids into a storage space below and thus have the advantage that they do not require bedding to absorb excreta and therefore do not require mechanical removal of soiled bedding and dung. Despite this, in Britain, solid floors have not been entirely superseded in commercial production, these floors are often the base of older or non-purpose built buildings used in pig production.

1.3 Lesions on pigs' feet, limbs and bodies and lameness

The floor surface is an important feature of the environment of an indoor housed pig because the animal is in constant contact with the floor, whether it be lying, standing or walking. Considerable previous work (discussed in detail in chapters 3 – 8) has indicated that pigs commonly develop lesions on the feet, limbs and bodies resulting from contact with the floor that they are kept on and floor type might also be associated with the prevalence of lameness.

1.3.1 Limb lesions

On single farms wounds on the limbs (Figure 1.1) have been reported in 80% (Penny *et al.*, 1971) and more recently 89% (Zoric *et al.*, 2004) of piglets. The most frequently affected site is the carpal joint of the forelimbs (Penny *et al.*, 1971; Svendsen *et al.*, 1979; Furness *et al.*, 1986). In the only cross sectional study published to date, Mouttotou *et al.* (1999a) reported 36% of piglets from 13 farms had skin abrasions.

In grower and finisher pigs high prevalences of soft tissue swellings occur on the limbs. In finished pigs at slaughter, the prevalence of bursitis (fluid filled sacs) and capped hock (fluid filled sacs on point of hock) has been reported to be between 51 - 87% and 3 – 11% respectively (Penny and Hill, 1974; Smith, 1993; Mouttotou *et al.*, 1998). Mouttotou *et al.*, (1999b) reported a prevalence of bursitis of 63% and capped hock of 0.7% on a cross section of 17 British farms. Calluses have also been reported to be highly prevalent with 40-100% of finishing pigs affected on 84 farms in Switzerland (Cagienard *et al.*, 2005)

Figure 1.1: Bilateral skin abrasions on the forelimbs of a piglet

Figure 1.2: Wound on the forelimb of a lactating sow

Photographs taken by A. KilBride

There are fewer studies on the prevalence of limb lesions in breeding sows. On a single unit von Berner *et al.* (1990) reported a prevalence of bursitis of 53%. But to date there are no published estimates of the prevalence of capped hock in sows. On 55 Austrian farms Leeb *et al.* (2001) reported that 90% of sows had calluses, but this estimate also included calluses on the body. Wounds on the limbs (Figure

1.2) have been reported in 22% of lactating sows on a British experimental unit (Edwards and Lightfoot, 1986) and 39% of sows in a cross sectional study of 10 Danish herds (Bonde *et al.*, 2004).

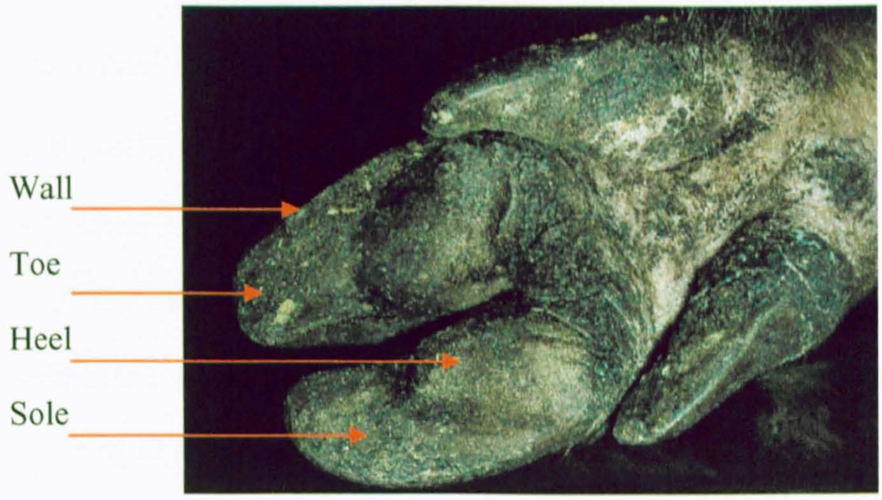
1.3.2 Body lesions

Lesions on the body have been reported on the shoulders of lactating sows and are frequently bilateral (Davies *et al.*, 1996; Zurbrigg, 2006). Body lesions range in severity from areas of alopecia and calcification to deep infected sores, often referred to as deducible ulcers (Zurbrigg, 2006). The prevalence of shoulder lesions ranged from 11% on a single unit (Davies *et al.*, 1996) to 5 -7% in culled sows at slaughter (Ritter *et al.*, 1999; Cleveland-Nielsen *et al.*, 2004).

1.3.3 Foot lesions

Pigs' feet have two surfaces; the hoof wall and the volar weight bearing surface. The volar surface has two distinct areas, the soft bulbous heel, which carries the majority of the weight (Webb, 1984) and the harder horn sole. Where the sole meets the hoof wall there is a thin contour of softer non pigmented horn, the white line. The anterior end of the sole, where it meets the hoof wall, is the toe (Figure 1.3)

Figure 1.3: A sow's foot with parts of the hoof labelled



Photograph taken by A. KilBride

1.3.3.1 Foot lesions in preweaning piglets

Sole bruising, presenting as red pigmentation on the weight bearing volar surface, has been reported in 87% (Zoric *et al.*, 2004) and 100% (Smith and Mitchell, 1977) of piglets on single farms (Figure 1.4).

Figure 1.4: Sole bruising on the foot of a preweaning piglet

Figure 1.5: Sole erosion on the foot of a preweaning piglet

Photographs taken by A. KilBride

In a cross sectional study of 13 British farms, 50% of piglets had sole bruising (Mouttotou *et al.*, 1999a). Sole erosion also occurs, where tissue is worn away from volar surface of piglets' feet (Figure 1.5).Smith and Mitchell (1977) reported sole erosion was present in 28% of piglets on a single unit. It is worth noting that historically these lesions have been referred to as sole bruising or sole erosion (Smith and Mitchell, 1977; Mouttotou *et al.*, 1999a) and this convention has been maintained in the current study. However, more correctly they affect the heel of the foot with involvement of the heel / sole junction.

1.3.3.2 Foot lesions in post weaning and adult pigs

As pigs mature the variety of different lesions that occur on their feet increases. Damage such as flaps of loose tissue (Figure 1.6), erosions (Figure 1.7) and cracks on their feet occur in 59-88% of culled gilts and sows (Ritter et al., 199; Gjein and Larssen, 1995; Knauer et al., 2007).

Figure 1.6: Heel flap on the foot of a lactating sow

Figure 1.7: Heel erosion on the foot of a lactating sow

Photographs taken by A. KilBride

1.3.4 Lameness

Lameness in pigs can have many causes, infectious arthritis or non infectious degeneration of the cartilage and bone of the joint (osteochondrosis) have been reported to be the most common (Dewey *et al.*, 1993; Jørgensen *et al.*, 1995; Kirk *et al.*, 2005). Traumatic damage to the limb or foot may also cause lameness (Smith 1988). Prevalence of lameness in finishing pigs has been reported to be between 1-4% (Smith and Morgan, 1997; Krieter *et al.*, 2004; van den Berg *et al.*, 2007) while the prevalence in breeding sows is estimated to be higher with between 9-15% of pigs affected (Gjein and Larssen 1995b; Bonde *et al.*, 2004; Heinonen *et al.*, 2006).

1.4 Impact of flooring on the prevalence of limb, body and foot lesions and lameness in pigs

An increased prevalence of bursitis and calluses on the limbs of grower and finisher pigs (Smith, 1993; Mouttotou *et al.*, 1998; 1999b; Guy *et al.*, 2002; Cagienard *et al.*, 2005; Scott *et al.*, 2006) and wounds on the limbs and bodies of lactating sows (Davies *et al.*, 1996; Zurbrigg, 2006) has been reported in pigs housed on slatted floors compared with solid concrete floors with bedding. Several studies have also indicated that increased prevalence of lameness may be associated with slatted floors compared with housing on solid concrete floors with bedding (Jørgensen, 2003; Heinonen *et al.*, 2006; Scott *et al.*, 2006). However, the effect of floor type on the prevalence of foot lesions is less clear; some lesions were more prevalent on slatted floors while other lesions were more prevalent on solid floors (Mouttotou *et al.*,1999a; 1999c; Scott *et al.*, 2006).

Abrasive floor surfaces may increase the risk of calluses and abrasions on the limbs (Svendsen *et al.*, 1979; Furniss *et al.*, 1986; Christison *et al.*, 1987; Mouttotou *et al.*, 1999a; Leeb *et al.*, 2001). Wet and dirty floors may soften the hooves and skin and make them more vulnerable to damage (Kroneman *et al.*, 1993a; Davies *et al.*, 1996; Zurbrigg, 2006) and increase the risk that injuries become infected (Gjein and Larssen, 1995b). Wet and dirty floors may also be slippery, which may increase the risk of a pig injuring themselves (Smith and Robertson, 1971; Gjein and Larssen, 1995c). Intrinsic factors, such as the thickness of the skin or fat layer that acts as a protective barrier, or the hardness of the hoof horn, may also affect the propensity of the pig to develop a lesion These factors may vary with age, breed and body condition (Penny and Hill, 1974; Davies *et al.*, 1996; Bonde *et al.*, 2004; Zurbrigg, 2006; Karlen *et al*, 2007; Knauer *et al.*, 2007).

There are more pigs housed outdoors in Britain than in any other EU country (Lara *et al.*, 2002). In 2003 approximately 30% of the national herd are housed outdoors (June census 2003, DEFRA). However, a comparison of the prevalence of injuries and lameness in indoor and outdoor housed pigs in Britain has, to the author's knowledge, never been completed. When comparing commercial production systems, outdoors housing offers pigs the greatest freedom to exhibit natural behaviour such as rooting, nest building and wallowing and is commonly assumed to be a 'high welfare' system. The soil is yielding and bedding is provided in the huts, therefore the prevalence of lesions and lameness might be expected to be low. However, in Croatia, Cox and Bilkei (2004) reported an increased prevalence of culling for lameness in outdoor housed sows. Clearly this is an area that merits further investigation in the British pig herd.

This research was funded by DEFRA to provide information on the floors pigs were housed on in commercial production in Britain and the likely impact of the floor on the health and welfare of pigs. This information is essential for policy makers to be able to understand the likely impact on the British pig industry of forthcoming legislation regarding flooring. This research was commissioned with particular reference to EC directive 2001/88/EC, which specifies slat and slot sizes for concrete slats for pigs of all ages. But the project was much broader than this and providing detailed information on the prevalence and likely impact of different floor design, material, condition and bedding commonly used in pig housing systems in Britain, including outdoor housing.

Is the welfare of pigs compromised by the floor they are housed on?

There is good evidence that lesions on pigs' feet, limbs and bodies arise as a pathological response to the environment the pig is housed in and, as such, are an indication that the environment is less than ideal. However, the affect of these lesions on the welfare of the pig is less easily defined. Debate surrounding sentience in farm animals, that is, whether they are aware of sensations and emotions and experience suffering and wellbeing, continues (Dawkins, 2006). However, animal welfare scientists have, by and large, agreed that farm animals should be given the 'benefit of the doubt' by assuming they are capable of suffering and promoting action to minimise this suffering (Webster, 2001). In light of this, farm animals were formally acknowledged as sentient beings by the European Union in 1999.

Webster (2001), states that the welfare of a sentient animal is good if it can sustain fitness and avoid suffering. Fitness, defined as health, normal growth and absence of injury, is measurable. However, an animal's state of mind, that is, whether it is suffering, can never be definitively known (Mason and Mendl, 1993). But Broom (1991) proposes that if an animal is able to adapt to and cope with the challenges that its environment poses, then it can avoid suffering.

As discussed by Webster (2005), an animal that is unproductive, could be unfit and this unfitness might be associated with suffering. As such, low productivity can be a good indication of poor welfare. However, productivity is not a sufficient measure of fitness or happiness of the animal, as productivity within acceptable levels can be associated with chronic pain, for example lameness in dairy cows.

Where the epidermis is damaged it is likely that the pig experiences pain. All vertebrates have similar pain receptors and nerve pathways and as humans experience pain with these types of injuries, it is likely pigs do too (Bateson, 1992). These injuries might be taken as an indication that the pig has not been able to adapt to its environment. Pain may be detectable in alterations in posture or gait. Lameness is widely used as an indication of poor welfare in dairy cattle, sheep, poultry and pigs (Kestin *et al.*, 1992; Whay *et al.*, 2003; Krieter *et al.*, 2004; Kaler and Green, 2008; Cagienard *et al.*, 2005; Heinonen *et al.*, 2006; Scott *et al.*, 2006).

In breeding sows, lameness is one of the major reasons for premature culling with 9-11% of premature sow culling attributed to lameness worldwide (Boyle *et al* 1998; Anil *et al* 2005a; Engblom *et al.*, 2007). When floor type or condition is associated with an increased prevalence of foot lesions and lameness (Gjein and Larssen, 1995b; 1995c; Jørgensen, 2003; Heinonen *et al.*, 2006), then it is evident that flooring is a factor that is affecting the welfare of the pig and additionally reducing productivity.

Slatted floors and lack of bedding, also restrict the pigs freedom to express natural behaviour, e.g., rooting and nest building. These floors have been reported to be associated with an increased prevalence of stereotypies, such as bar biting and maladaptive behaviours such as tail biting (Spoolder *et al.*, 1995; Moinard *et al.*, 2003; Scott *et al.*, 2006). However, the threat to a pig's welfare posed by intensive housing and lack of bedding must be balanced against the need to minimise risk of infection. The welfare of infected animals is likely to be compromised and poor herd health is often associated with reduced production. Slatted floors may reduce the contact between the pig and infectious pathogens in excreta, or aerial pollutants such as dust or ammonia (Scott *et al.*, 2006). Close confinement of animals indoors allows for close observation and better control of infectious sources. However, high density housing also increases the risk of disease spreading within the herd.

In a cross sectional study of the risks associated with proliferative enteropathy on commercial farms in the UK, contrary to expectations, slatted floors were associated with an increased risk of disease (Smith *et al.*, 1998). It is possible that in some cases early exposure to the pathogen may be protective. It is also possible that the floor type has less to do with the prevalence of disease by farm in the population than results from experimental studies indicate. Factors which determine the likelihood of introduction or persistence of disease on the farm such as herd size, farm density, and health status of incoming stock may override pen level, floor type effects (Woodbine *et al.,* 2007).

The five freedoms and provisions have been proposed by the Farm Animal Welfare Council (FAWC, 1993) to provide practical definitions of good welfare, as perceived by the animal, and stipulations of how good welfare might be promoted in the care of the animal. It is clearly evident from the results presented above that the housing of pigs on commercial farms commonly struggles to fulfil these criteria, particularly with regard to freedom from pain, injury and disease, freedom from discomfort and freedom to express normal behaviour (FAWC, 1993).

1.5 Using epidemiology to assess pig welfare on different floor types

When a welfare indicator can be defined, such as visible lesions or lameness, the prevalence in the population of interest can be measured by observation and epidemiological investigation. In order to improve welfare, the factors leading to poor welfare must be known. Cross sectional studies are commonly used to generate hypotheses about the risks associated with the prevalence of disease. Cross sectional studies can be a relatively quick and inexpensive method of collecting data on a wide range of outcomes, because each subject is just measured once and post or telephone questionnaires can commonly be used (Mann, 2003). However, where it is necessary to visit farms and examine animals to determine the prevalence of disease, costs associated with field work escalate. In a cross sectional study, a snapshot of prevalence and the associated exposures is taken. Therefore, it is not always possible to determine causality, because it is not known whether exposure occurred before or after the onset of disease, unless exposure is permanent, for example the sex of the animal (Levin, 2006).

As farms are highly variable and disease commonly multifactorial, it is often necessary to collect data on a large number of possible factors when attempting to identify associations between exposures and disease. This can make data collection and interrogation time consuming and complex. Correlation, that is a lack of variation, also poses a problem in epidemiological data. For example, if stocking density varies with floor type in commercial production (pigs more tightly stocked on slatted floors), then it is difficult to ascertain the effect of stocking density independent of the effect of floor type. When two or more variables are totally collinear it becomes impossible to separate their individual effects.

However there are also practical benefits to using an epidemiological approach to measure welfare outcomes, such as when an outcome is rare (e.g. swollen joints in preweaning piglets), and therefore a prohibitively large experimental sample would be required, or when diseases may be difficult or unethical (e.g. body sores) to elicit under experimental conditions, yet common on commercial farms (Green and Nicol, 2004). Epidemiological data may provide a more accurate model of the association between disease and exposure in the population than experimental data. The manner in which factors such as stocking density, hygiene or wear and damage vary with floor type on commercial farms is captured.

1.6 Conclusions

There is good evidence from experimental and small epidemiological studies, that pigs housed on standard commercial floors develop a high prevalence of foot, limb and body lesions. But the prevalence of these lesions and associated lameness, in the national herd is not known. These lesions are an indication that the floor the pig is housed on is less than ideal. Some outcomes are clear indications of poor welfare, such as lameness while other lesions might represent adaptation to the environment such as calluses. But more information is needed about the pathology of foot and limb lesions and whether sensitive tissue is damaged through inflammation or infection, to determine whether they are likely to be painful. The process of intensification of the pig industry has favoured slatted floors and minimal bedding for economic reasons, but there are no data on the current prevalence of different floor types in the national herd. More pigs are housed outdoors in this country than in any other, yet the effect of outdoor housing on the prevalence of foot, limb, body lesions and lameness is not known. These research questions are addressed by the following objectives.

1.6.1.1 Objectives

1. a. Estimate the prevalence of foot, limb and body lesions and lameness in pigs housed on commercial farms in England.

   b. Estimate the prevalence of different floor types commonly used on commercial farms in England.

2. Identify associations between the prevalence of foot, limb and body lesions and lameness and floor type in commercial farms in Britain.

3. Investigate the extent of pathological damage and correlations with clinical score of common foot and limb lesions on preweaner and grower pigs.

Chapter 2

Materials and methods and descriptive statistics

2.1 Introduction

In this chapter the materials and methods used to collect the data presented in chapters 3 – 8 are described.

2.2 Terminology

A wide range of ages and stages of pigs were examined in this study. These are defined in Table 2.1 below.

Table 2.1: Definition of terms used to describe groups of pigs

Term	Definition
Piglets	Pigs approximately 1 – 4 weeks of age still feeding from their mothers
Weaners	Weaned pigs aged between 4 – 8 weeks
Growers	Pigs aged between 9 – 15 weeks
Finishers	Pigs aged from 16 weeks to slaughter
Rearing pigs	Pigs between birth and slaughter
Post weaning pigs	Pigs between weaning and slaughter
Maiden gilts	Young female pigs prior to service
Pregnant gilts	Young pregnant female pigs and prior to the birth of their first litter
Gilts	Maiden or pregnant gilts
Sows	Multiparous lactating or pregnant females
Farrowing pens	Pens in which piglets and sows are housed for farrowing and lactation

2.3 Selection of sample farms

Farms were randomly selected from the database of members of Assured British Pigs (ABP). Assured British Pigs is a quality assurance scheme, members are visited quarterly by their farm veterinarian and yearly by ABP inspectors to ensure compliance with the food safety and animal welfare standards of the scheme. Fearne and Walters (2003) reported that in 2003 ABP had 2600 members which represented 90% of the national herd in England and Wales. The criteria for inclusion in the current study was that farms had more than 100 breeding sows and reared pigs from birth to slaughter. A total of 549 farmers in England and Wales which fitted these criteria were contacted by post over three rounds of invitations. Farmers were invited to participate in both the current project and a project investigating post weaning multisystemic wasting syndrome (PMWS). Reminders were sent out to non responders one month after the initial request. To increase sample size, additional convenience selected farms were recruited in Scotland with the help of Quality Meat Scotland and in England via their veterinarians.

2.4 Sample size calculations

Results from previous research (Mouttotou *et al.*, 1997; 1998; 1999a; 1999b; 1999c; 1999d) have indicated that the prevalence of foot and limb lesions in pigs in England is high. It was estimated that 90% of the pig farms in the English population would have pigs with foot and limb lesions. Because this study included pigs of all ages, for practical reasons it was necessary to sample farms which bred pigs and reared them to slaughter, here after referred to as breeder to finisher farms. According to the DEFRA 2003 census there were 1,870 breeder to finisher farms in England with more than 100 breeding sows. The average herd size of these farms was 210 sows. Assuming a population of 1,870, 95% confidence interval and 5% precision; it was calculated that it would be necessary to sample 129 farms.

Based on the number of pigs on the farms in the population that fitted the selection criteria, the approximate study population of preweaning piglets, post weaning pigs, breeding sows was 653, 275; 3 266, 375 and 391, 965 respectively. Assuming 50% lesion prevalence, a 95% confidence interval and 5% precision, it would be necessary to sample approximately 375 pigs in each of these groups if clustering within farms was ignored.

An estimation of the effect of the clustering of pigs within pens and farms was accounted for with the following formula:

$$n' = \text{n}(1 + \rho(m - 1))$$

Where n' is the corrected sample size estimate, n is the original sample size estimate, ρ is the intracluster correlation coefficient and m is the number of pigs sampled per farm (Dohoo *et al.*, 2003. p 43). With estimated farm and pen intracluster correlation coefficients of 0.1, the adjusted samples sizes were approximately 3,491 preweaning piglets, 5,629 post weaning pigs and 3,064 sows. In conclusion, based on these calculations, it was decided that approximately 12,200 pigs should be sampled from 129 farms to estimate prevalence in the current study.

To detect a two fold difference in risk between exposed and unexposed pigs with 95% confidence and 80% power given a 10% prevalence of disease in the unexposed pigs, a sample size of approximately 550 pigs are required for each risk factor analysis. Having accounted for a farm intracluster correlation coefficient of 0.1, the sample size increased to 2,695 piglets, 4,345 post weaning pigs, 1,595 gilts, 1,045 pregnant sows and 715 lactating sows. Pen level intracluster correlation coefficient was ignored in this calculation because pen was the bottom level for the majority of the risk factor analysis. Sample size calculations were carried out in Win Episcope 2.0.

2.5 Farm visits

Farm visits were carried out between August 2003 and August 2004. A team of researchers collected data both for the current study and the study of PMWS in pigs. Data were either collected by three researchers in one day or two researchers over two days. It took approximately 30 minutes for two people to examine each pen of pigs, including recording details of the floor. The data collection on each farm for the current study took approximately 16 person hours. Between 120-140 pigs were examined on each farm. This was approximately 5% of the population on the average sized farm.

To safeguard the biosecurity of the farms, 48 hours, or more if requested by the farmer, were left 'pig free' between farm visits. Therefore, each team visited a maximum of two farms per week. All equipment was either disposed of after each visit (e.g., unused recording sheets and protective clothing) or thoroughly disinfected (1% Virkon S, DuPont Ltd) and left 48 hours pig free before reuse (e.g., boots and clipboards).

2.6 Sample of pigs

Fifteen ages or stages of pig were examined on each farm (Table 2.2). When pigs of the correct age were not available the next closest in age was selected. Where age was used as a categorical variable the pigs outside of the stratifications are combined with the closest age group or if equidistant between two ages the pigs were combined with the younger age group. Table 2.2 summarises the data collected on pigs on each farm.

Table 2.2: Sample of pigs examined on each farm and data collected

	Age / stage	Number per farm	Lesion and lameness data collected			
			Limbs	Feet	Body	Lamenes
Piglets	1-week (3-7 days)	1 litter	✓	✓		
	2-week (8-14 days)	1 litter	✓	✓		
	3-week (15-21 days)	1 litter	✓	✓		
	4-week (22-28 days)	1 litter	✓	✓		
Weaner pigs	6-week	≤10 pigs	✓*	✓*		
	8-week	≤10 pigs	✓*	✓*		
Grower pigs	10-week	≤10 pigs	✓			
	12-week	≤10 pigs	✓			
	14-week	≤10 pigs	✓*	✓*		
Finisher pigs	18-week	≤10 pigs	✓			✓
	22-week	≤10 pigs	✓			✓
Gilts	Maiden gilts	≤10 pigs	✓*	✓*		✓
	Pregnant gilts	≤10 pigs	✓			✓
Multiparious sows	Lactating sows - mothers of piglets above	4 pigs	✓	✓	✓	✓
	Pregnant sows	≤10 pigs	✓*	✓*		✓

*Feet and limbs were examined on different pigs

2.7 Development of scoring systems and training of observers

A review of lameness, foot, limb and body lesion classification and scoring systems used in previous literature was carried out. Lesion classification systems were devised, or where possible, adopted from previous work with adaptations made as necessary (see section 2.9). Data recording sheets were designed for each age group which allowed data to be clearly and accurately recorded (Appendix C). Seven training farm visits were completed during August and September 2003. The scoring systems were tested, discussed and improved between the four researchers working on the project at this stage. Pigs were examined by the researchers collectively and individually and classifications and scores compared, until researchers felt confident that all were interpreting the definitions in the same manner. A comprehensive protocol was written detailing every lesion and score definition.

New staff joining the project were issued with the project protocol as part of their induction. Training sessions then took place with one of the experienced research staff as part of standard farm visits. The clinical presentation of each lesion / lameness score was considered and discussed in terms of the definitions as set out in the protocol. New staff worked with an experienced researcher (the experienced researcher was recorded as the observer) until both individuals felt confident that the protocol was understood and the new staff member had the skills to recognise and score the lesions and lameness. No formalised measures of interobserver or intraobserver reliability were taken.

2.8 Observations of pigs

Pigs of the appropriate ages (Table 2.2) were identified with the assistance of the farmer. A random number table was used to select a pen for observation from those of the appropriate age. Pens in the room or building were numbered by counting in a clockwise direction starting with the first pen on the left at the entrance. All piglets in selected litters were examined. In older ages, if there were ten or fewer pigs in the selected pen, all pigs were examined. If there were more than ten pigs in the pen, ten were haphazardly selected and examined.

Piglets and weaner pigs were held by the observer when examined. Growers, finishers, gilts and sows were free to move about the pen while the observations were made. They were generally relatively undisturbed by the researchers presence and allowed the researchers to touch and examine them. The gait of finisher pigs, gilts and pregnant sows was observed as they walked around the pen. Pigs that were unwilling to move were encouraged with pats on the rump, but if they did not respond no further attempt was made to force them to move. Pigs were identified with a coloured marker once they had been examined. Researchers worked in pairs; one person went into the pen, examined the pigs and relayed the information to a second researcher who remained outside the pen recording the observations. The identity of the researcher who examined the pigs was recorded on each data sheet.

2.9 Lesion classifications and scoring systems

2.9.1 Limb lesions in pigs of all ages

All four limbs of all pigs were examined. Data were collected on the prevalence and size of hairless patches, skin abrasions (known as wounds in lactating sow due to the differing aetiology), calluses, bursitis, capped hock and swollen joints or claws.

For clarity, it is worth defining the term bursitis as it will be used in the current study. Bursae are naturally occurring fluid filled sacs that minimise friction throughout the body where tendons glide over bones. Most correctly the term bursitis refers to inflamed naturally occurring bursae. Adventitious bursitis is the condition where bursae develop where they do not naturally occur. However, this study will follow the convention of previous literature of dropping the 'adventitious' prefix and using the term bursae (singular: bursa) to refer to these lesions and bursitis for the condition of having these lesions.

The classification of each type of limb lesion is presented in Table 2.3. Hairless patches, skin abrasions, bursitis and capped hock were classified as defined by Mouttotou *et al.* (1998; 1999ab). Size of the lesions was coded by comparison with the normal anatomy of the pig. The lesion was scored 0 - 3 as follows 0 = no lesion, 1 = <25%, 2 = 25-50%, 3 = >50% of the size of the nearest joint on the affected limb. Therefore a smaller pig with an absolutely smaller lesion could be given the same score to that of a larger lesion on a larger pig. The size of swollen joints or claws was scored on a 0-3 scale by comparing the lesion with the collateral unaffected joint or foot with 0 = no visible swelling, 1 = swollen to

<25%, 2 = swollen to 25-50%, 3 = swollen to >50% of the size of the normal joint / claw.

Table 2.3: Limb lesion classification

Lesion classification	Description
Hairless patch	Hair is missing but the epidermis is unbroken and no scab is present.
Skin abrasion / wound	Loss of the outer epidermis resulting in an open wound or a healing wound with a scab
Callus	Alopecia and hypercalcification of the skin
Bursa	Fluid filled sacs in the subcutaneous tissue
Capped hock	Bursa swelling on the point of the hock joint on the hind limb
Swollen joint or claw	Swelling of the tarsal, carpal, carpophalangeal, digital joint or the claws of the foot

2.9.2 Foot lesions

2.9.2.1 Preweaning piglets

All four feet of preweaning piglets were examined, where necessary, the feet were cleaned before examination. Sole bruising and erosion were recorded as defined by Mouttotou *et al.*, (1999) (Table 2.4). The lesions were scored according to the proportion of the heel surface that was affected as follows; 0 = no lesions, 1 = <25%, 2 = 25-50%, 3 = >50% affected.

2.9.2.2 Gilts and sows

The hind left foot of gilts and pregnant sows was examined while the pig was restrained to take a blood sample for the PMWS project. Indoor housed lactating sows were restrained in farrowing crates and so the hind left foot was examined while the sow was lying down in the crate. Outdoor housed lactating sows' feet were not examined because it was too difficult to catch and restrain them. Feet were not routinely cleaned before examination but were briefly wiped if they were very dirty. In addition to visual examination, feeling the foot was useful in the diagnosis of foot lesions.

Table 2.4: Foot lesions definitions

Lesion	Definition
Sole bruising	Congestion and bruising of the solar corium presenting as red or brown pigmentation
Toe / sole / heel erosion	Loss of horny tissue
Heel flap	Peeling of the superficial horn layer on the heel
Heel corrugation	Corrugated and flaky appearance to the heel
Overgrown claws	Long hooves with elongated toes and a concave sole
Unequal claw size	Visible inequality in size between the medial and lateral claw due to over growth in one claw
Wall crack	Crack on the axial or abaxial surface of the wall, which varies from a fine crack to a wide fissure with necrotic edges
Wall bruise	Dark red pigmentation on the horn of the wall
Wall penetration	Loss of part of the hard horn of the wall
White line crack	Cracks across the laminae separating the wall from the sole
White line separation	Penetration of the white line by debris with a visible gap

Foot lesions in gilts and sows were classified according to Mouttotou *et al.* (1997), with some small amendments to the terminology to clarify the lesions observed in the current study (Table 2.4). The severity of foot lesions was scored 0-3 as follows; 0 = no visible lesion, 1 = just identifiable lesion, 2 = clearly identifiable lesion but where structural damage is minimal, 3 = obvious lesion resulting in severe structural damage.

2.9.3 Body lesions on lactating sows

For the purpose of classification; lesions dorsal to the elbow joint (condyle of humerus) on the fore limbs and the stifle (lateral condyle of femur) on the hind limbs were classed as body lesions while lesions ventral to these joints were classified as limb lesions. Body lesions on lactating sows were classified as either a new lesion, or old scar and scored 1 -3 based on the severity and size of the lesion (Table 2.5). The location of the lesion on the sow's body was also recorded.

Table 2.5: Body lesion classification and scoring

Lesion	Definition	Score
Old scar	Healed with no blood or scabs evident	0 = no scaring 1 = small scar (<2cm) 2 = moderate scar (2-3cm) 3 = large scar (>3cm)
New lesion	Fresh, open or healing wounds with scabs	0 = no lesion 1 = redness/soreness where the surface of the skin is not broken or a small area of broken skin / scab (<2cm) 2 = moderate area of broken skin / scab (2-3cm) 3 = large area of broken skin / scab (>3cm)

2.9.4 Lameness scoring

Lameness in finishing pigs, gilts and sows was classified using the system developed by Main *et al.* (2000) (Table 2.6). It was necessary to amend the scoring system by omitting the section which involved letting pigs out of the pen,

Table 2.6: Lameness scoring (Main *et al.*, 2000)

Lameness score	Initial response to human presence	Behaviour of individual within the group	Standing posture	Gait
Score 0	Bright alert and responsive (pigs rise immediately and approach inquisitively)	Freely participates in group activity	Pig stands squarely on all four legs	Even strides. Caudal body sways slightly while walking. Pig is able to accelerate and change direction rapidly
Score 1	As for score 0	As for score 0	As for score 0	Abnormal stride length (not easily identified). Movements no longer fluent – pig appears stiff. Pig still able to accelerate and change direction
Score 2	As for score 0	May show mild apprehension to boisterous pigs	Uneven posture	Shortened stride. Lameness detected. Swagger of caudal body while walking. No hindrance in pig's agility
Score 3	Bright but less responsive (may remain down, or dog sitting, before eventually rising)	Apprehensive to boisterous pigs (usually remains separate from group activity)	Uneven posture. Will not bear weight on affected limb (appears to be standing on toes)	Shortened stride. Minimum weight-bearing on affected limb. Swagger of caudal body while walking. Will still trot and gallop.
Score 4	May be dull (only rises when strongly motivated)	Will try to remain separate from others within the group	Affected limb elevated off floor. Pig appears visibly distressed	Pig may not place affected limb on the floor while moving
Score 5	Dull and unresponsive	May appear distressed by other pigs in the group but may be unable to respond	Will not stand unaided	Does not move

because this was not practical when visiting a large number of farms. In lactating sows in farrowing crates only the sows' response to human presence and standing posture could be assessed. Younger ages of pig were not assessed for lameness as individuals would not walk calmly and independently about the pen to be scored, they tended to group with other pigs and run. Laminated copies of the lameness scoring system were taken on farm for reference when examining pigs.

2.9.5 Body condition scoring

The body condition score of gilts and sows was classified using a scoring system produced and published by DEFRA (Condition scoring of pigs, DEFRA PB3480). The body condition ranged from 1-5 with half points. Laminated copies with an illustration and description of each score were taken on every visit.

2.9.6 Size of the lactation crate

The relative size of lactating sows in relation to the crate in which they were housed was assessed by estimating the space between the sow and the crate while the sow was standing with her snout in the feed trough. Sows were encouraged to root in their trough either by tapping the trough or by activating their drinker. The distance between the sow's back and the top of the crate was classified as less than 5cm, 5-10cm or more than 10cm. The distance between the sow's tail and the back of the crate was classified as less than 10cm, 10–20cm or more than 20cm.

2.9.7 Pig group observations; cleanliness and slipping

The cleanliness of the pigs tended to be uniform within a pen, therefore a group assessment was made, with the exception of individually housed lactating sows. The percentage of the pigs' skin that was covered with dirt was classified 0 – 3 where; 0 = none, 1 = <25%, 2 = 25-50% and 3 = >50%.

Any pig observed slipping on the floor surface during the observation period was recorded as a pen level variable.

2.10 Pig data recorded from farm records

The parity of lactating sows was recorded from record cards in the farrowing house. The identification numbers of the sows whose feet were examined were recorded and this was used to look up their parity from the farmers records. The number of pigs in the pen was counted by the observer in small pens, in pens with more than approximately 50 pigs accurate counting was difficult. In these cases the farmer's records were consulted where possible. For each pen selected for observation, the time in weeks that the pigs had been in the current pen was established with the farmer. Pens of pigs that had been in the current pen less than one week were excluded from the study and another pen was randomly selected.

The farmer managing each pig unit was interviewed. The data collected included the herd size (number of breeding sows) and breed. The majority of the interview focused on data for the PMWS study.

2.11 Pen observations

Detailed information was recorded on the construction and condition of the pen or the condition of the paddock (Table 2.7). Pen size (cm), slat (mm) and slot (mm) measurements were made with a tape measure.

Table 2.7: Data collected on the pens and paddocks

Variable	Definition
Pen construction	
Floor type	Solid, partly slatted or fully slatted
Floor material	Soil, concrete, metal or plastic
Pen size (m^2)	Area calculated from length x width measurement
Steps in the pen	Height and location of each step
Slatted floors	
Dimensions of slats and voids (mm)	Slat width Void length Void width
Slat profile	Curved or flat
Shape of void	Rectangle, diamond, circular or triangle
Bedding	
Bedding material	Straw, wood shavings or paper
Bedding location	Farrowing pens; outside the crate, inside the crate All other pens; lying area, dunging area
Bedding depth	Deep; no floor surface visible Sparse; floor surface visible Deep / sparse: part of the floor deeply bedded and part of the floor sparsely bedded
Bedding condition	Cleanliness; clean, dirty or clean / dirty Dryness; dry, wet or dry / wet
Floor condition	
Cleanliness - presence or absence	Wet Dry slurry Wet slurry Spilled food Fresh dung
Damage - presence or absence	Sharp edges Broken / cracked Worn rough surface
Paddock condition	Grass cover; none, <25%, 25-50% or >50% Stones on the surface; none, <25%, 25-50% or >50% Ruts and holes; none, <25%, 25-50% or >50% Wet mud; none, <25%, 25-50% or >50%

The condition of the floor was examined in key areas of the pen. In post weaning, gilt and pregnant sow pens these were the lying area, dunging area, in front of the feeding and in front of the drinker. Fully slatted pens where the lying area and dunging area were not differentiated were considered as one single area. In farrowing pens the sows' dunging area within the crate was referred to as the dunging area, and all other space within the crate as the lying area.

2.12 Pathology

Pigs were selected for post-mortem examination from two convenience selected farms with contrasting floor types. The first farm had partly solid concrete and partly cast iron slatted floors in the farrowing houses and solid concrete floors in the grower and finisher accommodation. The second farm had fully plastic slatted floors in the farrowing house and fully concrete slatted grower and finisher accommodation. Two samples of bursa, capped hock, sole bruising, sole erosion, skin abrasion and swollen joints or claws of each score 0-3 were selected from each farm. Pigs were euthanased and examined post-mortem by a pathologist. The claws and samples from the limb lesions were preserved in formalin. Relevant tissues were then routinely embedded in paraffin and H and E stained sections were examined histologically. Each lesion was described by the pathologist using gross and histological examination and the severity of the internal lesion was compared with the clinical presentation. The depth of the horn layer on the heel in piglets' feet was measured. All pathology carried out by P. Ossent with the assistance of the author. Preparation of samples and histological examination was carried out by P. Ossent.

2.13 Data analysis

2.13.1 Data capture and management

Data were entered into Microsoft Office Access (2003) databases, in part by Warwick research staff and in part by a professional data entry company. Extreme values, that is outliers in continuous variables or impossible values in ordinal variables, were rechecked against the raw data and impossible values were deleted. Calculations of values such as stocking density, basic descriptive statistics and graphs were made in Microsoft Office Excel (2003).

2.13.2 Descriptive analysis

Correlations between ordinal categorical variables and between lesion score data within pigs were investigated using Pearson's correlation coefficient. Differences in proportions were investigated with chi-squared statistics. Differences between mean values were investigated with a t-test or an ANOVA with Bonferroni post hock testing, as appropriate. All descriptive analysis was carried out in Stata/SE 9.0 (StataCorp, USA. 2005)

2.13.3 Sample used in each analysis

Data from the farms randomly selected from the Assured British Pigs database, which will here after be referred to as the ABP farms, were used to calculate lesion prevalence and population attributable fractions. Pigs with incomplete data were excluded from prevalence calculations. The convenience selected farms in Scotland and England and the Welsh farm were included in the regression analysis and analysis of correlations between lesions.

2.13.4 Lesion prevalence

The prevalence of affected pigs was calculated from the ABP English farms for each lesion as follows;

$$\frac{\text{Number of pigs with lesion score one or above}}{\text{Total number of pigs examined on ABP farms}}$$

2.13.5 Regression analysis

The data from this study were clustered because pigs from the same farm, pen or litter were likely to be more similar to each other than pigs from different farms, pens or litters. To account for this, farm, pen or litter were included in the model as random effects and multilevel regression analysis was carried out

2.13.5.1 Multilevel mixed effect logistic regression

The definition of an affected pig in the logistic regression analysis for the majority of the outcomes was a pig with a lesion score one or above. The exception to this was capped hock and calluses in lactating sows, where due to high prevalence, an affected pig was defined by a lesion score two or above. Due to low prevalence; wall bruises, penetrations and cracks were combined into one lesion, as were overgrown and unequal claws.

In models where predictor variables did not vary between pigs in a pen, two level models were built with pens clustered within farms; the outcomes were calculated as follows:

$$\frac{\text{Number of affected pigs from the sample examined in the pen}}{\text{Number of pigs examined in the pen}}$$

In models where predictor variables varied between pigs within the same pen, e.g., body condition score, pig was included as a bottom level therefore the outcome was binary: 1 = affected pig, 0 = unaffected pig. A logit link function was used in all models.

2.13.5.2 Building logistic regression models

The housing and the type of lesions on the pigs changed with age, therefore the data were split into four age groups for analysis; piglets, post weaning pigs, pregnant sows with gilts and lactating sows. The age of the pig in weeks was also included throughout the initial (bivariable) screening of piglet and post weaning pig predictor variables and forced into final models.

Many of the pen variables were correlated with floor type, e.g. the use of bedding, therefore it was necessary to analyse sections of data separately. Results from these sub models were used to create single floor type and bedding variables which allowed all pen types to be analysed in one model. The association between continuous variables and the outcome was checked for linearity in bivariable analysis by categorising into five groups and checking for a pattern of increasing or decreasing coefficients. When deciding which variables to take on to further analysis the presence of missing data, the strength of the association (p value) and the biological plausibility of the variable were considered.

Models were built in three stages. First, each predictor variable was screened to check for an association with the outcome. Variables associated with the outcome at $p<0.2$ were taken forward to the second multivariable stage (Dohoo et al., 2003 p.321-322). In the multivariable model both forward addition and backward elimination were used (Dohoo et al., 2003 p.327-328) to select variables that improved model fit by $p<0.05$. Finally, all remaining variables were re-introduced to the model to check for residual confounding (Cox & Wermuth, 1996). All regression analysis was carried out in MLwiN version 2.01 (Rabash et al., 2000). Tables of odds ratios (OR) and confidence intervals (CI) are presented in the text. When the confidence interval did not include unity (1), the variable was significantly different from the reference category at $p < 0.05$.

2.13.5.3 Logistic regression model equations

The two level piglet and post weaning pig models, where the outcome was a proportion of the pigs affected, took the form:

$$\text{Logit}(p_{ij}) = \beta_0 + \sum\beta x_{ij} + \sum\beta x_j + v_j + u_{ij}$$

Where p_{ij} = proportion of affected pigs, β_0 = constant, βx is a vector of fixed effects varying at level 1 (ij) or level 2 (j), i is pens or litters, j is farms and $v_j + u_{ij}$ are the levels two and one residual variance.

The two level lactating sow and maiden gilt feet models, with a binary outcome, took the form:

$$\text{Logit}(p_{ij}) = \beta_0 + \sum\beta x_{ij} + \sum\beta x_j + v_j + u_{ij}$$

Where p_{ij} = the probability of an affected lactating sow or maiden gilt, β_0 = constant, βx is a vector of fixed effects varying at level 1 (ij) or level 2 (j), i is lactating sows / gilts, j is farms and v_j is the level two residual variance

The three level gilt and pregnant sow models, with a binary outcome, took the form:

$$\text{Logit}(p_{ijk}) = \beta_0 + \sum\beta x_{ijk} + \sum\beta x_{jk} + \sum\beta x_k + v_k + u_{jk}$$

Where p_{ij} = the probability of an affected gilt or pregnant sow, β_0 = constant, βx is a vector of fixed effects varying at level 1 (ijk), level 2 (jk) or level 3 (k), i gilts and pregnant sows, j is pens and k is farms, v_k + u_{jk} are the levels three and two residual variance.

2.13.5.4 Multilevel mixed effect multinomial regression

Multinomial models were used to investigate the risks associated with differing capped hock and gait scores. These models were run using the variables identified as significantly associated with the outcome in the binomial models. An unordered structure was assumed. The odds ratios and confidence intervals from the models are interpreted in the same way as those from the binomial models

The equations for each level of the categorical outcome of the four level unordered logistic models took the form:

$$\text{Logit}(p_{ijkl}) = \beta_0 + \sum\beta x_{jkl} + \sum\beta x_{kl} + \sum\beta x_l + f_l + v_{kl}$$

Where p_{ijkl} = the probability of each lesion / gait score occurring, β_0 = constant, βx is a vector of fixed effects varying at level 2 (jkl), level 3 (kl), or level 4 (l), i is the within pig response indicator, j is pigs, k is pens and l is farms, $f_l + v_{kl}$ are the residual variance at levels four and three.

2.13.5.5 Model fit

The Hosmer-Lemeshow goodness of fit test (Dohoo et al., 2003 p360-361) was used to investigate the difference between observed values and values predicted by the model. Paired observed and predicted data points were sorted by the predicted values. The data were summed into six groups, observed and predicted values were summed and compared with a Pearson chi-squared goodness of fit test with five degrees of freedom. An assumption of the chi-squared statistic is that no cell should have a value of less than one and 80% of cells must have values greater than five (Dohoo et al., 2003, p132). To ensure this occurred there were not always an equal number of data points in each category and for some models less than six groups were made. Graphs of the observed and predicted values, in this case split into deciles to give a better visual representation of the data, were also plotted. The Hosmer-Lemeshow statistic was not calculated for multinomial models because it was a poor indication of fit when the outcome was binary with a large number of zeros in the data, this is discussed further in Chapter 9.

2.13.6 Population attributable fractions

Population attributable fractions were calculated for indoor housed pigs compared with outdoor housed pigs using the following formula:

$$AF_p = RD * p(E+) / p(D+)$$

Where AF_p is the population attributable fraction, RD is the risk of a lesion in the exposed group minus the risk in the reference category group, p(E+) is the proportion of pigs on each floor type and p(D+) is the proportion of pigs with the lesion on each floor type (Dohoo *et al.*, 2003 p.128-130).

2.13.7 Observer differences

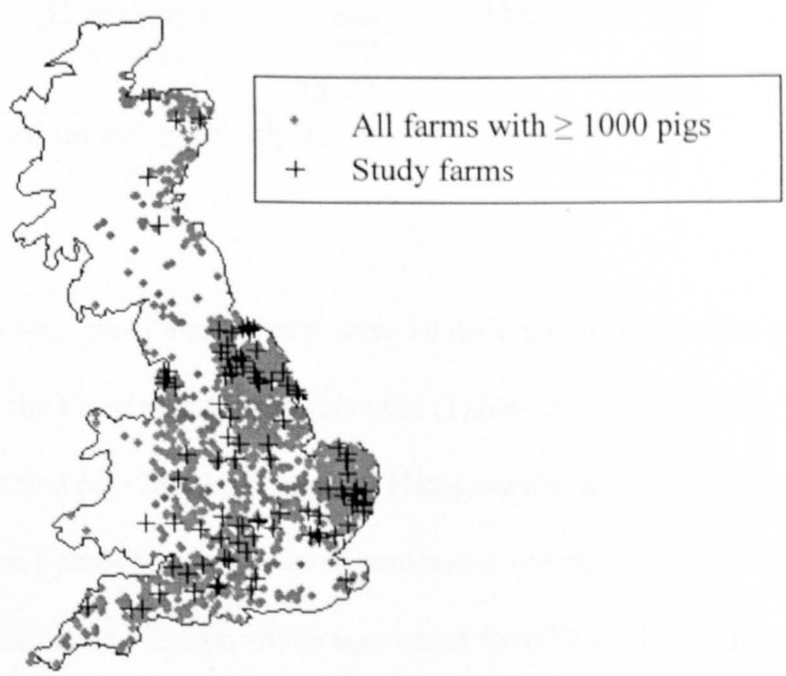
Eight researchers examined the pigs and these, plus a further three researchers examined the pens. These researchers did not all work on the project at the same time. The author and four other researchers (two other PhD students, a research assistant and a field technician) collected data for the full duration of the project. Six other technicians worked on the project for between two and eight months. The identity of the researcher was recorded for every observation. This information was added to each complete model to investigate the impact on interpretation of the fixed effects.

2.14 Descriptive summary of the study farms and pens

2.14.1 Sample of farms and pigs

A total of 101 of the 549 farmers contacted agreed to take part in the study; seven of these were used as pilot visits. An additional nine farms were convenience selected, five in Scotland and four in England. Data from a total of 103 farms are presented in this study. There were farms from all levels of the pyramid structure in the sample; 5 were nucleus units, 4 were multiplier units and 94 were commercial units. Pigs were housed indoors at all production stages in 83 farms and outdoors at least one production stage on 21 farms. The median herd size of the ABP farms was 320 sows (IQR 220, 475) while the mean, (for comparison with national mean), was 409 sows. Outdoor farms in the study (including convenience selected farms) were larger than indoor with a median herd size of 600 (IQR 355, 800) compared with 290 (IQR 202, 390) ($t(23) = -3.81$, $p<0.001$). Two farms had less than 100 sows due to changes in circumstance, but were included in the study. The farms randomly selected from the Assured British Pig database were in all areas of England but only one farm in Wales participated in the study (Figure 2.1). Therefore, the calculations of lesion prevalence and population attributable fractions were restricted to English herds only.

Figure 2.1: Map of study farms in England, Scotland and Wales (Woodbine *et al.*, 2007)



In total, 12,341 pigs from 1,623 pens on 103 farms were examined (Table 2.8). This was 26 less farms than the sample size calculations stipulated. The sample size of lactating sows in the risk factor analysis and was around half the estimated sample size required to detect a two fold difference in risk between exposed and unexposed pigs. With the actual sample size of 338 lactating sows there was sufficient power to detect a 2.5 fold difference in risk between exposed and unexposed pigs given 10% disease prevalence in the unexposed sample, α error = 0.05 and β error = 0.2.

Table 2.8: Total number of pigs examined in the study by age and type of pig

Group of pigs	Approximate age	All farms Number of pigs	Number of pens	ABP farms* Number of pigs	Number of pens
Piglets	3-28 days	3206	339	2843	304
Post weaning pigs	6-22 weeks	6386	651	5505	581
Maiden gilts	6 months +	801	98	707	88
Pregnant gilts	8 months +	744	95	638	86
Pregnant sows	12 months +	866	102	741	90
Lactating sows	12 months +	338	338	304	304
Total		12341	1623	10738	1453

*randomly selected and invited to participate

2.14.2 Breed line

The majority of pigs were crossbreeds, there were 10 different crosses on the 92 farms where data on the breed of pig were collected (Table 2.9). Numerically crosses with a pigmented pig (Duroc, Pietrain or Hampshire) were more common on outdoor farms than indoor farms. The most common cross on outdoor farms was Large White x Landrace x Duroc which accounted for 67% of the outdoor farms. In indoor farms the three most common crosses were Large White x Landrace (54.1% of farms), Large White x Landrace x Duroc (18.9% of farms) and Large White x Landrace x Pietrain (13.5% of farms). In the remainder of this thesis the term 'breed line' will be used to refer to different breed crosses.

Table 2.9: Breed line of pigs on sample farms

Breed line	Indoor farms n	Outdoor farms n	Total n
Large White	0	1	1
Landrace	2	1	3
Large White x Landrace	40	1	41
Landrace x Duroc	1	0	1
Large White x Landrace x Duroc	14	12	26
Large White x Landrace x Pietrain	1	0	1
Large White x Landrace x Pietrain x Hampshire	1	0	1
Large White x Landrace x Hampshire	1	1	2
Large White x Landrace x Duroc x Pietrain	4	1	5
Large White x Landrace x Pietrain	10	0	10
Landrace x Duroc x Pietrain	0	1	1
Total number of farms	74	18	92

2.14.3 Floor type

The majority of farms (91.2%) had more than one type of floor. When housing for pigs of all ages was considered, 96.4% of farms had some solid floors, 76.2% had some partly slatted floors, 65.5% had some fully slatted floors and 20.4% housed some stages outdoors on soil. The most prevalent floor type varied by age of pig (Table 2.10). When the total population of rearing pigs from birth to slaughter was considered (making assumptions about the floor type of the pigs that were not examined based on the flooring of pigs of the nearest age) it was estimated that 35.8% were housed on solid floors, 35.5% were housed on partly slatted floors and 28.7% were housed on fully slatted floors.

In the rearing herd the prevalence of pigs housed outdoors decreased with age while the prevalence of solid concrete floors indoors increased with age. Partly slatted floors were used most frequently for preweaning piglets while fully slatted floors were used more commonly for post weaning pigs (Weaners, growers and finishers, Table 2.10). The majority of gilts and multiparious sows were housed indoors on solid concrete floors; just 7% were housed on partly or fully slatted floors (Table 2.10). Sows that were housed on slats during pregnancy were more likely to be housed on solid concrete floors during lactation than sows housed on solid concrete floors with bedding during pregnancy (data not shown).

Table 2.10: Number and percent of pens by floor type

	Piglets and lactating sows		Weaners		Growers		Finishers		Gilts and pregnant sows	
Floor type	n	%	n	%	n	%	n	%	n	%
Soil	50	14.8	26	13.3	26	9.9	5	3.1	34	12.5
Solid concrete	35	10.4	45	23.1	111	42.2	68	42.5	218	80.4
Partly slatted	210	62.1	56	28.7	68	25.9	38	23.8	15	5.5
Fully slatted	43	12.7	68	34.9	58	22.1	49	30.6	4	1.5
Total n	338		195		263		160		271	

2.14.4 Slat material

Concrete slats were more prevalent in older age groups, whereas metal and plastic slats were more prevalent in farrowing and weaner pig pens (Table 2.11). There were only two farrowing pens with concrete slats so these were excluded from analysis of slat type.

Table 2.11: Number and percent of pens by slatted floor material

Slat type	Piglets and lactating sows n	%	Weaners n	%	Growers n	%	Finishers n	%	Gilts and pregnant sows n	%
Concrete	2	0.8	3	2.4	54	43.9	82	96.5	21	95.5
Metal	104	41.4	43	35	21	17.1	0	0	0	0
Plastic	109	43.4	77	62.6	48	39	3	3.5	1	4.5
Metal and plastic	36	14.3	0	0	0	0	0	0	0	0
Total n	251		123		123		85		22	

The prevalence of different slat materials varied with the type of floor within the age group of pig. In the 41 farrowing pens, 61% of fully slatted floors were made of plastic and a further 29.3% had metal slats under the sow and plastic slats elsewhere. In weaner pig pens, 85.1% (57 / 67) of fully slatted floors were plastic while in finisher pig pens 93.8% (45 / 48) of fully slatted floors were made from concrete. In the 57 fully slatted grower pig pens both plastic (56.1%) and concrete (38.6%) slats were used; there was a small proportion with metal slats (5.3%).

Metal slats used in farrowing pens were more variable than metal slats used in post weaning pens. There were seven different types of metal slat in the farrowing pens: cast iron (n=79), galvanised metal (57), round weld mesh (13), punched metal slats (9), expanded metal plastic coated slats (4), expanded metal slats (3) and woven wire mesh (1).

2.14.5 Slat dimension

The shape and dimensions of the slat and void was associated with the slat material (Table 2.12). In grower and finisher pig pens, where concrete slats were predominantly used, only 5% (7/129) of the slats were within dimensions specified by the directive (Council directive 2001/88/EC). The void was too wide in 92% (118/129) of the pens and the slat was too narrow in 25% (32/129) of the pens. In concrete slatted gilt and sow pens 67% (14/21) of the pens the dimensions of the concrete slats were outside of the directive. The void was too wide in 43% (9/21) of pens and the slat was too narrow in 24% (5/21).

Table 2.12: Properties of concrete, plastic and metal slats in 337 post weaner pens

	Concrete slats	Plastic slats	Metal slats
Void size cm^2	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

2.14.6 Bedding use

Bedding was present in 50% of preweaner, 37% of weaner, 57% of grower, 49% of finisher and 92% of gilt and pregnant sow accommodation. Deep straw bedding, where none of the ground surface was visible, was provided for all outdoor housed pigs in huts set on soil. In indoor pens, no bedding was used in fully slatted pens, while the majority of solid concrete pens had bedding. There was one pregnant sow pen and eight post weaning solid concrete pens without bedding. Due to small numbers these pens were combined with pens with sparse bedding for further analysis. Partly slatted farrowing pens were used either with or without bedding. In 210 partly slatted farrowing pens, 27.6% had bedding on all areas of solid concrete, 24.3% had some areas bedded and some areas unbedded and 48.1% had no bedding. Inside the crate area, 38.1% of the sows on partly slatted floors had bedding. In post weaning pens, the majority of part slatted floors had bedding. There were 18 (11.1%) partly slatted post weaning pens with no bedding. Due to the small number these pens were combined with the partly slatted post weaning pens without bedding for further analysis. There were only 19 gilt and pregnant sow pens with slats on the floor; this included four fully slatted with no bedding; ten partly slatted with no bedding and five partly slatted with bedding. Due to the small numbers these pens were combined into one 'slatted' group for further analysis.

2.14.7 Bedding type

All pigs housed outdoors were bedded with straw. In the 144 indoor farrowing pens with bedding; 58.3% had straw, 35.4% had sawdust / wood shavings and the remaining 6.3% had paper or a combination of paper and another bedding type. In the 301 post weaning pig pens with bedding 96.7% had straw and 3.3% had sawdust / wood shavings. All bedding provided for gilts and pregnant sows was straw.

2.14.8 Dryness and cleanliness of bedding

Preweaning piglets and lactating sows had clean and dry bedding more frequently than post weaning pigs or gilts and pregnant sows. Numerically the wetness and dirtiness of bedding were associated (Table 2.13).

Table 2.13: Number and percent of pens with clean and dry bedding

	Clean bedding		Clean / dirty bedding		Dirty bedding		Total overall	
	n	%	n	%	n	%	n	%
Piglets and lactating sows								
Dry bedding	76	87.4	6	6.9	5	5.7	87	65.4
Dry / wet bedding	9	25.0	22	61.1	5	13.9	36	27.1
Wet bedding	1	10.0	1	10.0	8	80.0	10	7.5
Total	86	64.7	29	21.8	18	13.5	133	
Post weaning pigs								
Dry bedding	43	79.6	7	13.0	4	7.4	54	18.1
Dry / wet bedding	11	4.8	199	87.7	17	7.5	227	75.9
Wet bedding	0	0.0	2	11.1	16	88.9	18	6.0
Total	54	18.1	208	69.6	37	12.4	299	
Gilts and pregnant sows								
Dry bedding	29	74.4	8	20.5	2	5.1	39	17.8
Dry / wet bedding	5	3.1	148	91.4	9	5.6	162	74.0
Wet bedding	0	0.0	0	0.0	18	100.0	18	8.2
Total overall	34	15.5	156	71.2	29	13.2	219	

2.14.9 Depth of bedding

The majority of bedding in farrowing pens was sparse, none had deep bedding. Deep bedding was mostly frequently provided for weaning pigs and the prevalence of deep bedding decreased with increasing age of pig (Table 2.14). Deep bedding was less likely to be wet and dirty in all age groups of pig compared with sparse bedding (data not shown).

Table 2.14: Number and percent of pens by bedding depth

	Deep bedding		Deep / sparse bedding		Sparse bedding		Total n
	n	%	n	%	n	%	
Piglets and lactating sows	0	0.0	32	22.9	108	77.1	140
Weaners	44	62.0	14	19.7	13	18.3	71
Growers	76	55.5	38	27.7	23	16.8	137
Finishers	23	31.5	28	38.4	22	30.1	73
Gilts and pregnant sows	88	34.9	101	40.1	63	25.0	252

2.14.10 Environmental enrichment

In the post weaning pig pens without bedding, 58.8% had manipulateable objects, which might be termed 'toys', added to enrich the environment. The most frequently provided items were chains (56.0%) plastic balls (10.8%) or plastic pipes (10.1%). No toys were provided in farrowing or gilt and pregnant sow pens without bedding.

2.14.11 Floor condition

The condition of the floor was varied with the floor material and provision of bedding. In Table 2.15 the prevalence of key floor conditions on each floor type is presented. Farrowing pens with solid concrete floors had the lowest prevalence of dry / wet slurry or damage on the floor while fully slatted farrowing floors were the least likely to be worn and rough. In post weaning pens, solid concrete floors with deep bedding were more likely to be wet and least likely to be damaged. Part slatted pens were least likely to have a coating of dry slurry or be worn and rough. Fully slatted floors were most likely to be damaged. In gilts and pregnant sow pens, solid concrete floors with deep bedding in all areas were less likely to be wet, have wet or dry slurry or be damaged or worn than other floors types. In this age group slatted floors were most likely to have dry slurry and be worn and rough.

Table 2.15: Number and percent of each floor type with wet, dry slurry, wet slurry, damage or worn rough floors

	Wet		Dry slurry		Wet slurry		Damaged		Worn /rough		Total
	n	%	n	%	n	%	n	%	n	%	n
Farrowing pens											
Solid concrete with bedding	12	44.4	2	7.4	1	3.7	0	0.0	4	14.8	27
Partly slatted with bedding	19	33.3	26	45.6	22	38.6	6	10.5	10	17.5	57
Partly slatted with some bedding	26	52.0	30	60.0	13	26.0	18	36.0	16	32.0	50
Partly slatted with no bedding	46	47.9	51	53.1	30	31.3	33	34.4	33	34.4	96
Fully slatted	14	34.1	29	70.7	14	34.1	2	4.9	2	4.9	41
Total overall	117	43.2	138	50.9	80	29.5	59	21.8	65	24.0	271
Post weaning pig pens											
Solid concrete with deep bedding	71	89.9	15	19.0	43	54.4	11	13.9	33	41.8	79
Solid with deep / sparse	69	89.6	13	16.9	44	57.1	9	11.7	30	39	77
Solid with sparse bedding	51	100	13	25.5	32	62.7	6	11.8	25	49	51
Partly slatted	42	76.4	2	3.6	30	54.5	14	25.5	2	3.6	55
Fully slatted	136	90.1	87	57.6	92	60.9	51	49.7	74	19.2	151
Total overall	369	89.3	130	31.5	241	58.4	91	22.0	164	39.7	413
Gilt and pregnant sow pens											
Deep bedding in all areas	37	74.0	3	6.0	15	30.0	2	4.0	6	12.0	50
Sparse / deep bedding in all areas	71	97.3	18	24.7	50	68.5	5	6.8	18	24.7	73
Sparse bedding in all areas	41	91.1	6	13.3	32	71.1	6	13.3	16	35.6	4[illegible]
Deep bedding in the lying area	17	81.0	7	33.3	19	90.5	5	23.8	5	23.8	2[illegible]
Sparse bedding in the lying area	11	84.6	2	15.4	11	84.6	1	7.7	2	15.4	1[illegible]
Slatted	17	89.5	8	42.1	14	73.7	4	21.1	13	68.4	1[illegible]
Total overall	194	87.8	44	19.9	141	63.8	23	10.4	60	27.1	22

2.14.12 Steps in the pen

There were steps in 47.5% (307 / 646) of post weaning pig pens and 75.9% (186 / 245) of gilt and pregnant sow pens (Table 2.16). None of the farrowing pens had steps. Steps were most commonly located between the lying and the dunging area in both post weaning pig pens (66.1%) and gilt and pregnant sow pens (88.7%) the rest were in front of feeders and drinkers. The median height of the biggest step in the pen was 10 cm (IQR 7, 15) in post weaning pig pens, and 11 cm in gilt and pregnant sow pens (IQR 10, 15).

Table 2.16: Number and percent of pens by number of steps present

Number of steps in the pen	Post weaning pig pens		Gilt and pregnant sow pens	
	n	%	n	%
0	342	52.9	59	24.1
1	208	32.2	110	44.9
2	77	11.9	57	23.3
3	19	2.9	18	7.3
4	0	0	1	0.4
Total n	646		245	

2.14.13 Farrowing pens

The median size of 272 indoor farrowing pens, including the creep area where present, was 4.7 m^2 (IQR 4.3, 5.3). Farrowing pen size varied by floor type. Fully solid pens were the largest (median 5.1 m^2), part slatted next largest (median 4.8 m^2) and fully slatted pens were the smallest (median 4.3 m^2). There was a designated creep area, either an enclosed creep or a mat, in 69.0% (181 / 289) of farrowing pens. Creep areas were less common in pens with fully slatted floors (37.2%) than partly slatted (68.6%) or solid concrete floors (67.7%).

2.14.14 Paddocks

The paddocks of 26 groups of gilts, 17 groups of pregnant sows and 50 lactating sows with litters of piglets were examined. The condition of the paddocks varied in grass cover, stones on surface, ruts and holes and wet mud (Table 2.17).

Table 2.17: Number and percent of 93 gilt, pregnant sow and lactating sow paddocks by ground condition

Percent of paddock	Grass cover		Stones on the surface		Ruts and holes		Wet mud	
	n	%	n	%	n	%	n	%
None	44	47.3	13	14.0	11	11.8	23	24.7
<25%	13	14.0	48	51.6	61	65.6	43	46.2
25-50%	12	12.9	21	22.6	18	19.4	12	12.9
>50%	24	25.8	11	11.8	3	3.2	15	16.1

Of the 93 paddocks observed; 36.4% were classified as flat, 48.6% had a just identifiable slope, 12.1% had a clearly identifiable slope and 2.8% of paddocks were on a steep slope.

2.15 Descriptive summary of the study pigs

2.15.1 Litter size

The litter size of preweaning piglets at the time of examination ranged from 3-16 with a mean of 9.7 (SD 1.9). The mean litter size at the time of observation was smaller in piglets housed outdoors (mean 8.8, SD 2.5) than in litters housed indoors (mean 9.6, SD 1.9) ($t(59) = 2.19$, $p < 0.05$). There was a negative correlation between the parity of the sow and the litter size at the time of observation ($r = -0.15$, $df = 338$, $p<0.05$).

2.15.2 Body condition score of gilts and sows

The mean body condition score was 3.1 (SD 0.3) for maiden gilts, 3.3 for pregnant gilts (SD 0.4), 3.0 (SD 0.5) for pregnant sows and 2.9 (SD 0.5) for lactating sows. Body condition score varied significantly between these type of pig ($F(3, 2506) = 60.5$, $p<0.001$). Maiden gilts had a significantly lower body condition score than pregnant gilts ($F(3, 2506) = 0.13$, $p<0.001$), but a higher body condition score than pregnant sows ($F(3, 2506) = -0.06$, $p < 0.05$) and lactating sows ($F(3, 2506) = -0.22$, $p<0.001$). Pregnant gilts had a significantly higher body condition score than pregnant sows ($F(3, 2506) = -0.20$, $p<0.001$) and lactating sows ($F(3, 2506) = -0.35$, $p < 0.001$). Pregnant sows had a higher body condition score than lactating sows ($F(3, 2506) = -0.16$, $p < 0.001$). The body condition of indoor housed sows did not differ from outdoor housed sows. However, maiden ($t(167) = 2.98$, $p<0.01$) and pregnant gilts ($t(243) = 2.62$, $p<0.01$) housed outdoors had a lower body condition than gilts housed indoors.

2.15.3 Sow parity

The parity of sows examined for foot lesions (Chapter 7) ranged from 1-14 with a median of 3 (IQR 2, 4). The parity of lactating sows examined for foot, limb body lesions and abnormal posture (Chapter 5) ranged from 1-14 with a median of 3 (IQR 3, 5). However, because the parity of sows was unknown in 20.0 % of lactating sows, parity was not included in multivariable analyses.

2.15.4 Skin cleanliness

Numerically preweaning piglets were the cleanest, while finishing pigs were the dirtiest age group (Table 2.18).

Table 2.18: Number and percent of groups of pigs and individual lactating sows by percent of skin covered with dirt

	None		<25%		25 – 50%		>50%		Total
	n	%	n	%	n	%	n	%	n
Piglets	143	44.3	178	55.1	2	0.6	0	0	323
Post weaning	35	5.9	298	50.3	185	31.3	74	12.5	592
Gilts	10	5.7	95	54.0	53	30.1	18	10.2	176
Pregnant sows	2	2.2	38	42.7	36	40.4	13	14.6	89
Lactating sows	18	6.1	210	70.9	53	17.9	15	5.1	296

Piglets were most frequently dirty when housed in partly slatted farrowing pens with little or no bedding. Lactating sows housed outdoors, or indoors in partly slatted farrowing pens with little bedding, were dirtiest (Table 2.19).

Table 2.19: Number and percent of piglets with any dirt on their skin and lactating sows with >25% of their skin covered with dirt by floor type

Floor type	Preweaning piglets n = 323 litters		Lactating sows n = 296 sows	
	n	%	n	%
Solid concrete with bedding	13	41.9	6	18.2
Partly slatted with bedding in all areas	29	52.7	21	21.9
Partly slatted with bedding in some areas	28	58.3	-	-
Partly slatted with no bedding	63	64.3	24	26.1
Fully slatted	24	57.1	4	10.8
Outdoor with deep bedding	23	46.9	13	34.2

Post weaning pigs were dirtiest when housed outdoors or indoors with sparse bedding or on partly slatted floors (Table 2.20)

Table 2.20: Number and percent of pens of post weaning pigs, gilts or pregnant sows with >25% of their skin covered with dirt by floor type

Floor type	Post weaning		Gilts		Pregnant sows	
	n	%	n	%	n	%
Solid concrete with deep bedding	25	30.5	6	18.8	4	30.8
Solid concrete with deep / sparse bedding	30	39.4	17	42.5	18	58.1
Solid concrete with sparse bedding	28	50.9	12	34.3	3	33.3
Solid deep bedding in lying area	-	-	3	25.0	3	60.0
Solid sparse bedding in lying area	-	-	2	28.6	4	57.1
Partly slatted partly solid concrete	78	50.6	6	46.2	4	57.1
Fully slatted	61	35.9				
Outdoor with deep bedding	37	67.3	22	75.9	13	86.7

2.15.5 Group size

In post weaning pigs the median group size (number of pigs in the pen) was 30 (IQR 16, 52) and ranged from 5 - 400. The median group size was 11 (IQR 8, 14) for maiden gilts, 10 (IQR 7, 18) for pregnant gilts and 23 (IQR 9, 60) for pregnant sows. In post weaning pigs group size was negatively correlated with age ($r = -0.23$, $df = 616$, $p < 0.05$) (Table 2.21).

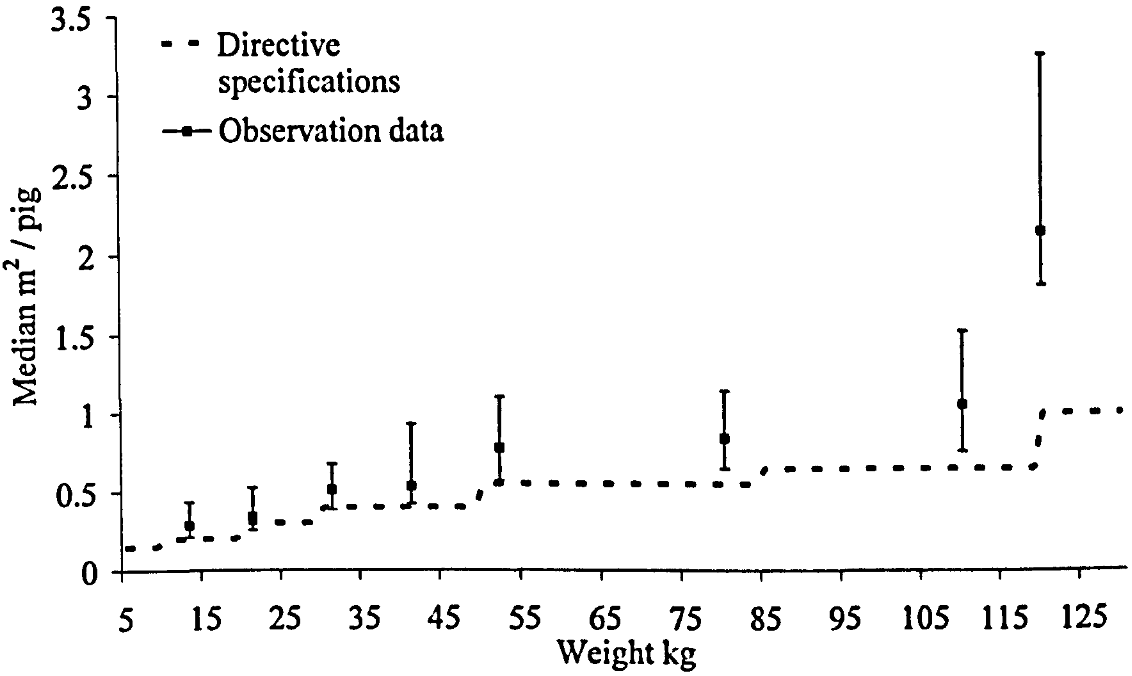
Table 2.21 Median and IQR of number of pigs in the pen by age

Age in weeks	n	Median	IQR
6	96	40	24, 71
8	95	39	20, 68
10	83	34	20, 62
12	89	33	22, 53
14	94	26	15, 50
18	85	20	14, 34
22	76	15	11, 25

2.15.6 Space allowance and stocking density

The median space allowance for post weaning pigs ranged from 0.3 m^2 / pig at 6-weeks old up to 1.1 m^2 / pig at 22-weeks old (Figure 2.2). These values include pigs housed in pens set on soil outdoors. The median value from the study farms was within the EU regulations (Council directive 2001/88/EC) (Figure 2.2); however there were a proportion of each age of pig that were over stocked.

Figure 2.2: Median and IQR range m^2 / pig aged 6 – 22 weeks from the study farms plotted against the stocking directive specifications



The stocking density regulations are calculated on the weight of the pig (Council Directive, 2001). Data from the MLC pig year book 2006 were used to approximate the weight of the pigs in this study based on their age (Table 2.22).

Table 2.22: Percent of pens overstocked by age based on estimated weight

Age (weeks)	Average weight (kg) (MLC Pig Yearbook 2006)	Total n	Percent overstocked
6	13	94	19.1
8	21	92	41.3
10	28.5	80	8.8
12	37	86	22.1
14	46	90	8.9
18	58	83	6
22	83	78	7.7

There was a trend in weaner, grower and finisher pigs for the space allowance to correlate with the floor type and bedding use. Pens with the most bedding were most loosely stocked while slatted pens were the most tightly stocked (Table 2.23).

Table 2.23: Median and IQR range of m^2 / post weaning pig by floor type

	Weaning pigs			Grower pigs			Finisher pigs		
	n	Med	IQR	n	Med	IQR	n	Med	IQR
Outdoor with deep bedding	18	0.6	0.5, 0.7	46	0.8	0.6, 0.9	15	0.9	0.9, 1.5
Solid concrete with deep bedding	13	0.5	0.3, 0.6	33	0.8	0.6, 1.1	27	1.4	1.2, 1.8
Solid concrete with deep/sparse bedding	10	0.5	0.4, 0.7	22	1.0	0.7, 1.4	22	1.3	1.1, 1.6
Solid concrete with sparse bedding	22	0.4	0.3, 0.5	21	0.7	0.5, 1.0	3	1.1	0.9, 1.3
Partly slatted partly solid	56	0.3	0.2, 0.3	62	0.5	0.4, 0.7	35	0.8	0.6, 1.0
Fully slatted	62	0.3	0.2, 0.3	56	0.4	0.4, 0.5	46	0.7	0.6, 0.9

The median space allowance in gilts and sows was 2.1 m^2 / maiden gilt (IQR 1.7, 3.0) and 2.8 m^2 / pregnant gilt (IQR 2, 3.8) and 3.0 m^2 (IQR 2.5, 4.3) per pregnant sow. Pregnant gilts and sows in small groups were most likely to be over stocked (Table 2.24).

Table 2.24: Number and percent of overstocked gilt and pregnant sow pens by group size

	Group size	n	%	Total n
Maiden	1-5	1	2.9	34
gilts	6-39	18	17.3	104
	>40	0	0	0
Pregnant	1-5	5	38.5	13
gilts and	6-39	7	21.2	33
sows	>40	1	4.8	21

These figures exclude gilts and sows housed outdoors because they had free range paddocks and the space per pig was relatively unrestricted. Again, there was a trend for maiden gilts, pregnant gilts and pregnant sows housed on slatted floors to be the most tightly stocked. Maiden and pregnant gilts were most loosely stocked on floors with deep bedding in all areas while pregnant sows were most loosely stocked on solid concrete floors with deep bedding in the lying area and sparse bedding in the dunging area or deep bedding in the lying area and no bedding in the dunging area (Table 2.25).

Table 2.25: Median and IQR of m^2 / pig for maiden gilts, pregnant gilts and pregnant sows by floor type

	Maiden gilts			Pregnant gilts			Pregnant sows		
	n	Med.	IQR	n	Med.	IQR	n	Med.	IQR
Deep bedding in all areas	20	2.8	2.1, 2.8	18	3.2	2.4, 3.2	15	2.9	2.5, 2.9
Deep / sparse bedding all areas	20	2.2	2.0, 2.2	20	3.0	2.0, 3.0	29	3.3	2.6, 3.3
Sparse bedding all areas	21	2.1	1.7, 2.1	15	2.6	2.0, 2.6	9	3.1	2.9, 3.1
Deep bedding in the lying area	7	2.0	1.7, 2.0	7	3.1	2.0, 3.1	7	3.3	2.5, 3.3
Sparse bedding in the lying area	5	2.0	1.7, 2.0	2	3.0	2.9, 3.0	6	2.3	1.9, 2.3
Slatted	8	1.4	1.2, 1.4	5	2.0	1.8, 2.0	7	1.9	1.8, 1.9

2.15.7 Pigs slipping

Pigs were observed slipping in 41.5% of post weaning pig pens and 35.1% of gilt and pregnant sow pens. Pigs were observed slipping more frequently on slatted pens and pens with little bedding (Table 2.26).

Table 2.26: Number and percent of pens where post weaning pigs, gilts and pregnant sows were observed slipping by floor type

		Post weaning pigs n = 569		Gilts and pregnant sows n = 202	
Floor type		n	%	n	%
Solid with deep bedding in all areas		9	12.2	5	13.2
Solid with deep / sparse bedding in all areas		20	27.0	26	36.1
Solid sparse bedding in all areas		29	53.7	17	38.6
Solid deep bedding in the lying area		-	-	8	57.1
Solid sparse bedding in the lying area		-	-	7	50.0
Slatted	partly	87	56.1	14	70.0
	fully	84	51.9		
Outdoor		7	14.0	9	20.9

2.16 Discussion

The study farms were not a true random sample, but are thought to be a reasonable representation of the English pig farm population in 2003. Data were collected from pig farms in all areas of the country, with more farms sampled from the pig dense areas of North Yorkshire and East Anglia. While only 20% of the study farms housed pigs outdoors, these farms housed approximately 30% of the total number of breeding sows in the study herds, which reflected the indoor : outdoor ratio in the national herd in the June 2003 (June 2003 census, DEFRA).

However, the mean herd size of the study farms was almost twice as large as the mean herd size of farms fitting the selection criteria in the national herd (breeder to finisher farms with more than 100 breeding sows) (June census 2003, DEFRA). This might have occurred because the number of sows per herd increased between June 2003, when the census was taken, and August 2004, when data collection for the current study was completed (June census 2006, DEFRA). There might also have been some bias in the sample because farmers with larger herds had more staff and therefore felt more able to accommodate the demands of the study. It is unclear how this might have biased the data, it is possible that larger farms might have newer floors and more intensive systems, but it remains unknown. It is also unclear whether breeder to finisher herds were representative of the whole industry, but for practical purposes it was necessary to maximise the data collection effort by sampling from farms where all ages of pigs were present.

Assured British Pigs was the best sampling frame available, reportedly representing 90% of the national herd (Fearne and Walters, 2003). Sampling members of a quality assurance scheme might have resulted in a bias for farms with higher health and welfare standards. However, due to the high coverage, much of the variation in the population is captured within the sampling frame.

Compliance in this study was voluntary, only 18% of those invited to take part agreed and no data were available on the farms of non compliant farmers. This may have biased the sample towards motivated farmers with higher standards. This is unlikely to have a significant effect on the floor types on their farms or the associations with lesions and lameness, however the condition of the floors and the hygiene standards might have been higher than average.

The number of farms sampled (103) was smaller than the figure calculated for the sample size required (129). Farm numbers were constrained by the low compliance in those invited to take part. Among farmers who replied to say they did not wish to participate in the study; too time consuming, insufficient financial compensation for their time and biosecurity fears were common reasons for declining (Woodbine *et al.*, 2007). Despite the reduced sample size this study provides to date the largest study of the prevalence of foot and limb lesions and lameness on English pig farms.

Because data collection was combined with the PMWS project it was necessary to have a large team of field staff, furthermore there was a turnover in staff during data collection. This was problematic, because this project relied on the ability of researchers to identify and score lesions. While the lesions were well defined and every effort was made to ensure each new addition to the team was correctly trained, it is possible that the number of observers increased the misclassification and reduced the significant associations between lesions and environment.

It is likely that error in the data set also arose from the challenging environmental conditions. Light was sometimes poor and pigs' limbs and feet were dirty. It was too time consuming, and stressful for the pigs, to clean each foot and limb before examination. On dirty pigs it is likely that the prevalence of the less easily identifiable lesions was underestimated. The type of floor was associated with the dirtiness of the pigs. However, it is important to note that dirty pigs outdoors may be muddy while dirty pigs indoors are likely to be covered with faeces and therefore more likely to be associated with an increased risk of transmission of infectious diseases.

One of the challenges in the data collection was examining the feet of live gilts and sows. This was carried out while the sow was restrained with a snout snare. To minimise the stress and discomfort of this procedure only one foot per sow was examined and this sow was not examined for limb or body lesions or lameness. The hind left foot was chosen because prevalence of lesions has been reported to be higher on the hind feet (Kroneman *et al.*, 1993; Gjein and Larssen, 1995a; Knauer *et al.*, 2007).

The majority of the outcomes were ordinal. However, binomial models were used for the majority of the risk factor analyses because they had greater power to detect an association and produced more easily interpretable results than ordinal models. Ordinal models were used when the definition of an affected pig was unclear.

Within housing systems factors such as floor material, bedding use and floor condition were highly correlated, or multi co-linear (Dohoo *et al.*, 1997). When variables are interdependent in this way it is not possible to ascertain the individual effect of each variable on the outcome. For this reason, many variables measured, such as slat dimensions or void shape, did not remain in the final models because of their collinear relationship with, in this case, slat material.

When deciding which variables to take on to further analysis the presence of missing data, the strength of the association and the biological plausibility of the variable were considered.

There was a large degree of variability in floor designs, floor materials and bedding use within study farms so farms could not be classified by their floor type. The impact of this variability was that the floor type the pig had been housed on at a younger age might be quite different to the floor the pig was housed on at the time of the visit, making causal associations with floor type difficult to detect. This situation was more likely as the pigs' age increased.

There was a large range of housing and management systems in place across the study farms. In a number of areas, farmers appeared to fail to comply with regulations which govern the housing of pigs in the EU (Council directive 2001/88/EC; Commission directive 2001/93/EC). One of these areas was the lack of provision of a malleable material for rooting. This is perhaps not surprising because it is unclear how this can be provided in fully slatted pens on a commercial farm. In approximately half of the pens without bedding 'toys' were provided, but these do not satisfy the requirements of the directive. There also appeared to be a proportion of pens (approximately 16%) which were stocked at a higher density than specified by the directive. However, these results must be interpreted with caution because the results were based on an average growth curve by age. If pigs were considerably lighter than the average for their age they would not have been over stocked. Finally, based on this sample of farms, it would appear likely that a large number of English farms will be outside of the new regulations on void width in concrete slats when this directive comes into force in 2013. However, it is probable that the void widths between concrete slats increase as the slats wear, so it is unclear how slats should be measured and how, in practice, the measurements specified in the directive should be interpreted.

2.16.1 Conclusions

Data were collected on a total of 103 British pig farms (nine convenience selected); 21 farms kept at least one stage of pigs outdoors and 82 farms kept all pigs indoors. The farms selected from the ABP database are believed to be representative of the English national herd. The data provide a good estimate of the pen types and floors, body condition and stocking density in the national herd. Pen and floor construction was associated with bedding use and pig age. This information was used in further analyses in Chapters 3-8.

Chapter 3

Limb lesions in post weaning pigs

Some of the contents of this chapter have been published as the following:

KilBride, A.L., Gillman, C.E., Ossent, P. and Green, L.E. (2008). A cross-sectional study of the prevalence and associated risk factors for capped hock and the associations with bursitis in weaner, grower and finisher pigs from 93 commercial farms in England. *Preventive Veterinary Medicine*. 83, 272-284. (Appendix A)

Gillman, C.E, KilBride, A.L., Ossent, P. and Green, L.E. (2008). 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. *Preventive Veterinary Medicine*. 83, 308-322. (Appendix B)

3.1 Introduction

Post weaning pigs commonly develop calluses, bursae and capped hock on their limbs. Calluses, described as areas of alopecia and hypercalcification (Cagienard *et al.*, 2005), develop in response to repeated contact with a hard or abrasive surface (Leeb *et al.*, 2001). A thickened epidermal layer forms that may protect the skin against further damage. Bursae and capped hock present as swellings on pigs' limbs that are caused by fluid filled sacs in the subcutaneous tissue. Bursae develop below the hock joint on the lateroplantar, plantar and medial planes on the hind limbs and at a lower prevalence on the forelimbs (Mouttotou *et al.*, 1998). A capped hock is a bursal swelling over the point of the tarsus (hock) of the hind limb (Penny and Hill 1974).

Mouttotou *et al.*, (1999b) reported a prevalence of bursitis and capped hock of 63% and 0.7% respectively in a survey of 912 live pigs aged 8-28 weeks from 17 farms in England. In finished pigs at slaughter, the prevalence of bursitis and capped hock has been reported to be between 51-87% and 3-11% respectively (Penny and Hill, 1974; Smith, 1993; Mouttotou *et al.*, 1998). In a cross sectional study of 84 farms in Switzerland, the prevalence of calluses in finishing pigs was between 57 – 89% on the fore limbs and 42 - 99% on the hind limbs. Significantly higher prevalences of calluses were reported in pigs housed on fully concrete slatted floors compared with pigs housed on floors with solid concrete and straw bedding (Cagienard *et al.*, 2005).

In previous studies of risk factors for bursitis and capped hock the two lesions were combined into one outcome variable for analysis. Risk factors identified were presence of slatted floors and lack of bedding (Smith, 1993; Mouttotou *et al.*, 1998; 1999b; Guy *et al.*, 2002; Scott *et al.*, 2006), metal slats compared with plastic (Smith, 1993), high stocking density (Smith, 1993), steps in the pen (Mouttotou *et al.*, 1999b) and wet slurry on the floor (Mouttotou *et al.*, 1999b). Penny and Hill (1974) reported a reduced risk associated with pigmented breeds of pigs. However, having accounted for the effect of different management systems, Guy *et al.* (2002) did not detect any effect of breed on the prevalence of bursitis.

Although capped hock and bursitis have been combined in previous studies it has been hypothesised that the risks associated with capped hock may be distinct to those for bursitis. Mouttotou *et al.* (1999b) proposed that the lack of cushioning between the calcaneous and the skin at the point of the hock makes this area particularly vulnerable to injury. Therefore, factors which increase the risk of pigs slipping and falling may be particularly important in the aetiology of capped hock. Smith (1993) proposed that differences between individual pigs determined whether a pig developed capped hock or bursitis. He reported a negative association between the prevalence and severity of capped hock and bursitis which he attributed to differences in lying and sitting posture. However, this negative association could also occur if the associated risks for capped hock and bursitis were distinct and uncorrelated.

von Berner *et al.* (1990) reported that the response of the pig indicated acute bursitis were painful when palpated. However, other researchers have stated capped hock and bursitis are unlikely to be painful (Probst *et al.*, 1990; Smith 1993) or cause lameness (Bäckström and Henricson 1966; Orsi 1967; Probst *et al.*, 1990). Indeed it is possible that these swellings may provide padding that protects against further discomfort. The impact of these lesions on the welfare of the pig remains unclear. However, it is clear that the presence of calluses, bursitis and capped hock indicate that the pig has made a pathological response to its environment. Therefore, the prevalence of such lesions may provide a good indication of the suitability of the animal's environment and an indication of well being (de Koning, 1985).

In this chapter, the prevalence, associated environmental risks and population attributable fractions for capped hock, bursitis and calluses in post weaning pigs are reported. In addition, a description of the pathology of capped hock and bursitis and typical histological findings are presented.

3.2 Materials and methods

3.2.1 Data collected

On each farm, seven pens of post weaning pigs between six and 22 weeks of age were randomly selected. All four limbs of all pigs, up to a maximum of 10 per pen, were examined for calluses, bursae and capped hock (Chapter 2, Table 2.3). The pens the pigs were housed in were examined and details of construction and condition, with particular attention to the floor, were recorded (Chapter 2,Table 2.7). Risks associated with the prevalence of limb lesions were investigated in binomial logistic regression models. In addition, a multinomial model was used to investigate the risks associated with capped hock score zero, one and two or three in indoor housed pigs. Outdoor housed pigs were excluded from the multinomial model of capped hock because of the low prevalence of score two and three lesions. For further details on the data analysis see Chapter 2, section 2.13.

3.2.2 Sample of pigs

A total of 6,386 post weaning pigs were examined. Out of this total; 5,505 pigs were from the ABP English farms and 881 were from the additional convenience selected farms. Of the total 6,386 pigs; 5,839 were housed indoor and 547 were housed outdoors.

3.2.3 Pathology

Two samples each of capped hock and bursae of score one, two and three were selected from two farms. Each lesion was described by the pathologist (P.Ossent) using gross and histological examination (Chapter 2, section 2.12).

3.3 Results

3.3.1 Prevalence of limb lesions in 5,505 post weaning pigs

The prevalence of calluses, bursitis and capped hock in 5,505 post weaning pigs was 45.5%, 40.6% and 16.9% respectively. The prevalence of lesions score one to three varied by lesion type (Table 3.1). Calluses were more prevalent on the fore limbs and bursitis was more prevalent on the hind limbs. Lesions were equally prevalent on the right and left limbs (Table 3.1).

Table 3.1: Number and percent of 5,505 post weaning pigs with limb lesions by limb and score

		Calluses		Bursitis		Capped hock	
		n	%	n	%	n	%
Limb	Fore right	2217	40.3	385	7.0		
	Fore left	1604	29.1	370	6.7		
	Hind right	597	10.8	1808	32.8	853	15.5
	Hind left	600	10.9	1801	32.7	837	15.2
Score	Score 0	2999	54.5	3270	59.4	4576	83.1
	Score 1	1068	19.4	1120	20.3	660	12.0
	Score 2	1091	19.8	817	14.8	232	4.2
	Score 3	347	6.3	298	5.4	37	0.7
Total affected score 1 - 3		2506	45.5	2235	40.6	929	16.9

The prevalence of limb lesions in post weaning pigs varied with age, floor type, slat material, floor condition, breed line and skin cleanliness (Table 3.2)

Table 3.2: Number and percent of post weaning pigs with limb lesions by age, floor type, slat material, floor condition, breed line and skin cleanliness

	Calluses		Bursitis		Capped hock		Total
	n	%	n	%	n	%	n
Age							
6 weeks	473	56.0	151	17.9	18	2.1	845
8 weeks	377	43.0	253	28.8	50	5.7	877
10 weeks	328	43.0	314	41.2	109	14.3	762
12 weeks	369	45.7	346	42.9	154	19.1	807
14 weeks	314	37.2	398	47.2	184	21.8	843
18 weeks	321	43.1	409	55.0	189	25.4	744
22 weeks	323	51.6	362	57.8	225	35.9	626
Floor type							
Solid concrete deep bedding	205	26.5	186	24.1	78	10.1	773
Solid concrete deep / sparse bedding	215	32.0	202	30.1	140	20.9	671
Solid concrete sparse bedding	275	54.1	253	49.8	111	21.9	508
Partly slatted	812	59.9	623	46.0	213	15.7	1355
Fully slatted	844	60.7	847	60.9	316	22.7	1391
Outdoor	49	9.0	24	4.4	21	3.9	543
Slat material							
Concrete	618	57.4	707	65.6	339	31.5	1077
Plastic	635	64.7	466	47.5	126	12.8	981
Metal	352	60.5	243	41.8	41	7.0	582
Floor condition							
Pigs slipping on the floor	1177	39.9	991	33.6	396	13.4	2952
No pigs slipping on the floor	1141	54.7	1072	51.4	429	20.6	2086
Food on the floor in lying area	2213	45.6	1964	40.4	753	15.5	4856
No food on the floor in lying area	176	60.5	175	60.1	46	15.8	291
Slip marks in the dunging area	1925	45.8	1608	38.3	596	14.2	4199
No slip marks in the dunging area	499	48.4	550	53.3	226	21.9	1032
Worn rough floor	1321	42.7	1093	35.3	436	14.1	3093
No worn rough floor	993	49.8	980	49.1	363	18.2	1995
Breed line							
Non pigmented	1888	51.2	1660	45.0	650	17.6	3687
Pigmented	617	34.0	573	31.5	203	11.2	1817
Skin cleanliness							
No dirt on the skin	156	51.7	87	28.8	20	6.6	302
<25% of the skin dirty	1309	49.0	1046	39.1	391	14.6	2674
25 - 50% of the skin dirty	698	42.3	725	43.9	327	19.8	1651
>50% of the skin dirty	217	34.2	286	45.0	146	23.0	635

3.3.2 Risks associated with limb lesions in post weaning pigs

3.3.2.1 Calluses

The prevalence of calluses did not differ significantly with the age of the pig. There was a pattern of increasing risk of calluses as the depth of bedding on solid concrete floors decreased and a further increase in risk was associated with slatted floors, compared with pigs housed outdoors on soil with deep bedding (Table 3.3). There was no significant difference in the risk of calluses in pigs housed on partly slatted compared with fully slatted floors (Table 3.4.) The risk of calluses decreased as the proportion of the pig's skin that was covered in dirt increased (Table 3.3 and Table 3.5).

3.3.2.2 Bursitis

There was a significant increase in the risk of bursitis with each week increase in age from six to 22 weeks. The risk of bursitis in indoor housed pigs increased as the depth of bedding on the floor reduced and the proportion of the floor that was slatted increased, compared with pigs housed outdoors on soil with deep bedding. Having controlled for floor type there was an increased risk of bursitis in pens where there were marks of slipping in the dunging area, where there was food on the floor in the lying area and where there was a worn rough floor, compared with pens of pigs where these conditions were not observed (Table 3.3).

In pens with slatted floors there was an increased risk of bursitis in pigs housed on fully slatted floors compared with partly slatted floors. Having controlled for floor type, there was an increased risk of bursitis in pigs housed on metal slatted floors compared with concrete slats. There was an increased risk of bursitis in pens where there was a worn rough floor under the feeder, compared with pigs on slatted floors where these conditions were not observed (Table 3.4).

In pigs housed outdoors, or indoors on solid floors with bedding, there was an increased risk of bursitis where floors were wet and damaged and a reduced risk of bursitis where there was dung on the floor under the drinker, compared with floors where these conditions were not observed. There was a reduced risk of bursitis associated with pigmented pigs (Hampshire, Duroc or Meishan in their breed line) compared with non pigmented pigs (Large White or Landrace) (Table 3.5).

3.3.2.3 Capped hock

3.3.2.3.1 Binomial logistic regression

As with bursitis, there was a significant increase in the risk of capped hock in post weaning pigs with each week increase in age from six to 22 weeks. There was an increased risk of capped hock in pigs housed indoors in pens with solid concrete floors with deep and sparse bedding, solid concrete floors with sparse bedding, partly slatted and fully slatted floors compared with pigs housed outdoors on soil with deep bedding (Table 3.3 and Table 3.5). There was no significant difference in the risk of capped hock between pigs housed on partly and fully slatted floors. There was a reduced risk of capped hock associated with pigs housed on plastic and metal slated floors compared with pigs housed on concrete slatted floors (Table 3.4).

Table 3.3: Two level logistic binomial models of the risks associated with limb lesions in post weaning pigs housed on all floor types

	Calluses n = 592 pens		Bursitis n = 532 pens		Capped hock n = 618 pens	
Intercept coefficient	-0.7		-4.1		-4.4	
	OR	CI	OR	CI	OR	CI
Age (weeks)	1.0	1, 1	1.1	1.1, 1.1	1.2	1.2, 1.2
Floor / bedding						
Soil	1.0		1.0		1.0	
Solid concrete with deep bedding	3.3	1.7, 6.4	4.6	2.4, 9.0	1.9	0.9, 4.3
Solid concrete with deep / sparse bedding	4.0	2.0, 7.7	3.7	1.9, 7.2	3.2	1.5, 7.0
Solid concrete with sparse bedding	8.2	4.1, 16.2	9.0	4.5, 18.1	3.1	1.4, 7.0
Partly slatted	13.2	7.1, 24.4	8.0	4.3, 15.2	3.7	1.8, 7.7
Fully slatted	12.7	6.8, 23.7	18.8	10.0, 35.3	3.8	1.8, 7.9
Floor condition*						
Pigs seen slipping			1.3	1.0, 1.6		
Food on floor in lying area			1.6	1.1, 2.5		
Slip and skid marks in dunging area			1.5	1.1, 2.0		
Wear or visible aggregate			1.3	1.1, 1.6		
Skin cleanliness						
No dirt on the skin	1.0					
<25% of the skin dirty	0.8	0.5, 1.2				
25 - 50% of the skin dirty	0.6	0.4, 0.9				
>50% of the skin dirty	0.4	0.3, 0.7				
Random effects	Var.	SE	Var.	SE	Var.	SE
Farms	0.9	0.2	0.4	0.1	0.8	0.2
Pens	0.7	0.1	0.6	0.1	1.0	0.1
Hosmer-Lemeshow	χ^2	P value	χ^2	P value	χ^2	P value
goodness-of-fit	8.3	0.14	4.0	0.55	8.3	0.14

* The reference categories are pigs in pens where these conditions were not observed

Table 3.4: Two level logistic binomial models of the risks associated with limb lesions in post weaning pigs housed on slatted floors

	Calluses n = 311 pens		Bursitis n = 299 pens		Capped hock n = 324 pens	
Intercept coefficient	0.0		-3.0		-3.0	
	OR	CI	OR	CI	OR	CI
Age (weeks)	1.0	1.0, 1.1	1.2	1.1, 1.2	1.1	1.1, 1.2
Floor type						
Partly slatted	1.0		1.0		1.0	
Fully slatted	1.0	0.7, 1.4	1.2	1.1, 1.2	1.1	0.7, 1.7
Slat material						
Concrete	1.0		1.0		1.0	
Plastic	1.6	1.0, 2.5	1.4	0.9, 2.1	0.5	0.3, 0.9
Metal	1.5	0.9, 2.5	1.7	1.1, 2.8	0.4	0.2, 0.9
Floor condition*						
Pigs observed slipping†			1.4	1.04, 1.77		
Wear or visible aggregate under feeder			1.7	1.1, 2.4		
Skin cleanliness						
No dirt on the skin	1.0					
<25% of the skin dirty	0.9	0.5, 1.5				
25 - 50% of the skin dirty	0.6	0.3, 1.0				
>50% of the skin dirty	0.6	0.3, 1.2				
Random effects	Var.	SE	Var.	SE	Var.	SE
Farms	0.8	0.2	0.1	0.1	0.8	0.2
Pens	0.5	0.1	0.6	0.1	1.3	0.2
Hosmer-Lemeshow	χ^2	P value	χ^2	P value	χ^2	P value
goodness-of-fit	1.3	0.94	0.9	0.97	1.0	0.97

* The reference categories are pigs in pens where these conditions were not observed

† CI presented to two decimals places where it affected interpretation of the p value

Table 3.5: Two level logistic binomial models of the risks associated with limb lesions in post weaning pigs housed on solid floors with bedding

	Calluses n = 268 pens		Bursitis n = 255 pens		Capped hock n = 281 pens	
Intercept coefficient	-1.7		-3.9		-4.9	
	OR	CI	OR	CI	OR	CI
Age (weeks)	1.0	0.9, 1.0	1.9	1.0, 1.1	1.17	1.13, 1.21
Floor/bedding						
Soil	1.0		1.0		1.0	
Solid concrete with deep bedding	4.5	2.1, 9.5	4.5	2.1, 9.9	1.6	0.7, 4.0
Solid concrete with deep / sparse bedding	4.6	2.2, 9.6	4.6	2.1, 9.8	3.7	1.6, 8.5
Solid concrete with sparse bedding	8.6	4.0, 18.4	9.6	4.2, 21.8	3.9	1.6, 9.3
Floor condition*						
Fresh dung under drinker			0.6	0.4, 0.9		
Wetness on floor			3.6	1.9, 6.7		
Damage on the floor			1.6	1.1, 2.6		
Breed						
Non pigmented			1.0			
Pigmented			0.4	0.2, 0.7		
Skin cleanliness						
None - 25% of the skin dirty						
25 - 50% of the skin dirty	0.8	0.6, 1.1				
>50% of the skin dirty	0.4	0.2, 0.6				
Random effects	Var.	SE	Var.	SE	Var.	SE
Farms	1.5	0.3	0.8	0.2	1.3	0.3
Pens	0.4	0.1	0.3	0.1	0.6	0.2
Hosmer-Lemeshow	χ^2	P value	χ^2	P value	χ^2	P value
goodness-of-fit	2.2	0.82	3.5	0.62	2.6	0.76

* The reference categories are pigs in pens where these conditions were not observed

3.3.2.3.2 Multinomial regression of capped hock

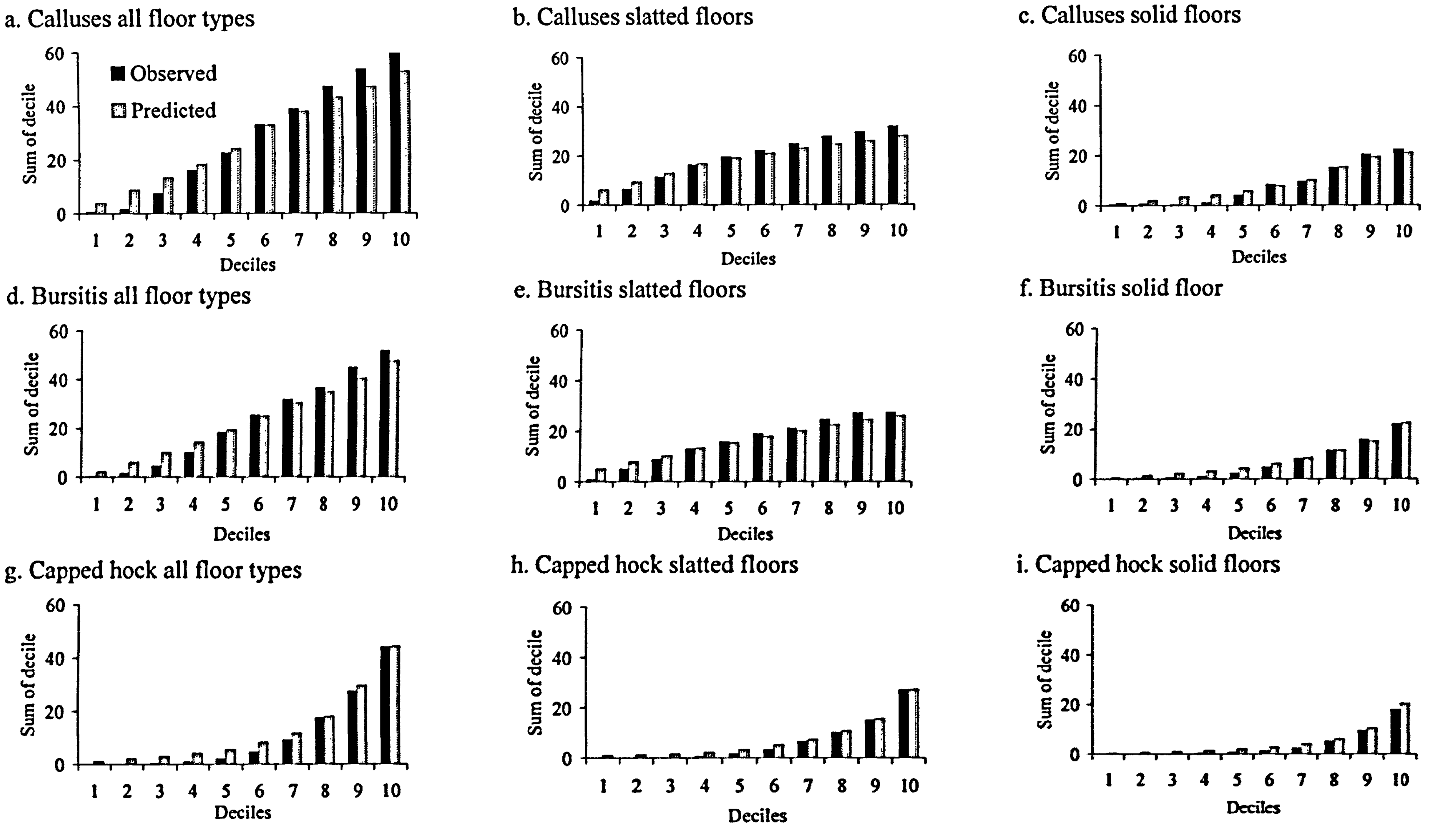
There was an increased risk of capped hock score one and score two or three, with increasing week of age. There was a significantly increased risk of capped hock score one and score two or three in pigs housed on partly slatted floors or fully slatted floors compared with pigs housed on solid concrete with deep bedding in all areas. The coefficients were larger for the capped hock score two or three than score one lesions (Table 3.6).

Table 3.6: A three level multinomial model of the risks associated with capped hock by score in 5,446 post weaning pigs on all indoor floor types

	Score 1		Score 2 / 3	
Intercept coefficient	-4.2		-6.2	
	OR	CI	OR	CI
Age (weeks)	1.1	1.1, 1.2	1.2	1.1, 1.2
Floor / bedding				
Solid concrete with deep bedding				
Solid concrete with deep / sparse bedding	1.7	1.0, 3.9	2.5	1.0, 6.3
Solid concrete with sparse bedding	1.8	1.0, 3.2	2.5	1.0, 6.5
Partly slatted	1.7	1.1, 2.8	3.9	1.7, 8.9
Fully slatted	1.8	1.1, 2.9	4.6	2.1, 10.3
Random effects	Var.	SE	Var.	SE
Farms	0.9	0.2	1.3	0.3
Pens	0.7	0.1	1.8	0.3
Covariance between scores				
Farms	0.7	0.2		
Pens	0.5	0.1		

In slatted pens the results from the multinomial model were similar to the logistic binomial model. There was a reduced risk of capped hock score one and capped hock score two and three associated with plastic (Score one: OR 0.6, CI 0.3, 1.0. Score two: OR 0.4, CI 0.2, 0.8) and metal (Score one: OR 0.5, CI 0.2, 0.9. Score two: OR 0.3, CI 0.1, 0.7) slats compared with concrete slats (full model not shown).

Figure 3.1: Graphs a-i of observed verses predicted values for logistic binomial regression models of limb lesions in post weaning pigs



3.3.2.4 Model fit and observer differences

The Hosmer-Lemeshow goodness-of-fit tests (Table 3.3, Table 3.4 and Table 3.5) and graphs of predicted verses observed values (Figure 3.1) indicated that the binomial models were a reasonable fit to the data. Controlling for the identity of the observer in the models did not significantly alter the interpretation of any of the fixed effects in the capped hock or callus models. The association between increased prevalence of bursitis and pigs observed slipping in the model with all floor types became non significant ($p = 0.11$) when the identity of the observer was added to the models. The interpretation of all other fixed effects associated with bursitis remained unchanged.

3.3.3 Population attributable fractions for limb lesions in post weaning pigs

Depending on the age of the pigs, the prevalence of calluses, bursitis and capped hock would be reduced by between 77-91%, 85-100% and 43 – 81% respectively if all pigs were housed outdoors. In all ages of pig the largest proportion of bursitis and capped hock was attributable to fully slatted floors and the next largest to partly slatted floors. In weaner and grower pigs, there were similar proportions of pigs affected with calluses attributable to partly slatted and fully slatted floors. In finishing pigs a higher proportion of calluses were attributed to fully slatted floors due to the higher prevalence of this floor type in older pigs (Table 3.7).

Table 3.7: Population attributable fractions for limb lesions in 5,505 post weaning pigs by floor type

	Calluses			Bursitis			Capped hock		
	Wea.*	Gro.	Fin.	Wea.	Gro.	Fin.	Wea.	Gro.	Fin.
Outdoor soil with bedding[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solid concrete deep bedding	5.3	7.8	4.3	2.2	9.9	5.8	5.2	6.6	0.4
Solid concrete deep / sparse bedding	3.9	8.0	9.7	1.2	8.1	12.6	0.0	10.9	9.1
Solid concrete sparse bedding	5.8	10.9	13.7	7.8	9.0	16.2	11.7	9.2	6.0
Partly slatted	31.9	28.7	26.4	31.1	26.1	25.3	23.5	18.3	10.3
Fully slatted	29.7	26.7	36.9	45.7	32.1	40.1	40.6	31.2	18.0
Total reduction	76.7	82.1	91.0	88.0	85.2	100.0	81.0	76.2	43.8

[a] Reference category

*Wea. = weaner, Gro. = grower, Fin. = finisher

3.3.4 Associations between limb lesions in post weaning pigs

In 6174 post weaning pigs there was a significant positive association within pig between the presence of calluses and bursitis (r (6174) = 0.20, $p<0.05$), calluses and capped hock (r (6174) = 0.08, $p < 0.05$) and bursitis and capped hock (r (6174) = 0.09, $p<0.05$).

3.3.5 Pathology of bursae and capped hock

The pathology of bursae score one and two appeared to be identical; bursal sacs with lumen were present and in some cases inflammatory cells or signs of haemorrhage were evident in the bursa wall (Figure 3.2 and Figure 3.3). However, in one of the four examples of bursae score three, a lumen was not present, the swelling comprised of solid connective tissue (Figure 3.4). The researchers did not detect a difference between the feel of solid lesions and lesions with a fluid filled lumen when palpating the swellings prior to pathological examination.

Figure 3.2: Histological section of a thick walled subcutaneous bursal sack (B) with a large lumen (A) and skin containing hair follicles and sweat glands (C)

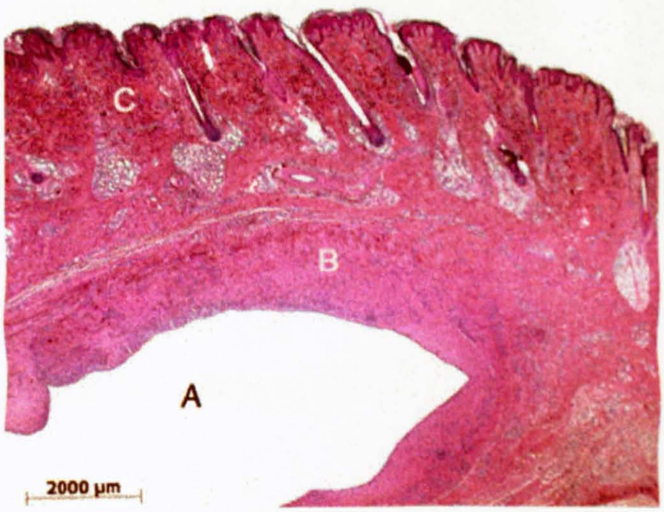


Figure 3.3: Bursa score two - bursal sac is visible (A)

Figure 3.4: Bursa score three - solid connective tissue (B)

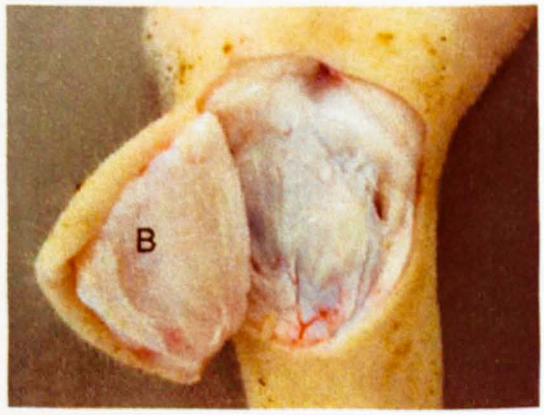


Figure 3.5: Capped hock score one - no bursal sac present only a layer of loose connective

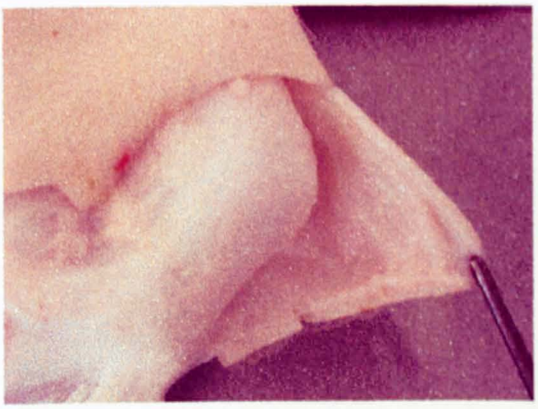


Figure 3.6: Capped hock score two - subcutaneous bursal sac containing blood-tinged watery fluid visible on the point of the hock

Photographs taken by P. Ossent

Fluid filled sacs were not present in the four examples of capped hock score one examined (Figure 3.5). The appearance of a swollen hock might have been a misclassification due to a proliferation of collagenous connective tissue. Capped hock score two lesions appeared to be pathologically identical to bursa score one or two lesions, with a clearly identifiable fluid filled sac (Figure 3.6). The pathology of capped hock lesions score three could not be investigated because no pigs with this classification were identified during visits to farms from which pigs for the pathology study were selected. Bursae and capped hock from pigs housed on different floor types did not have discernibly different pathology.

3.4 Discussion

The most notable difference in limb lesion prevalence between the current study and previous work was the higher prevalence of capped hock. Approximately 25 times more pigs had capped hock than reported by Mouttotou *et al.* (1999b) in a similar analysis, and between two (Penny and Hill, 1974) and six (Smith, 1993) times more than reported from abattoir surveys. The difference in prevalence might be a true difference, because slatted floors are increasingly common on English pig farms, or might have occurred due to scoring or observer differences. The prevalence of the largest capped hock lesions in the current study (score three) was close to the entire prevalence of capped hock reported by Mouttotou *et al.* (1999b). The simple presence / absence method of scoring capped hock used by Mouttotou *et al.* (1999b) might have resulted in pigs with mild lesions being classified as unaffected.

In the current study, fluid filled sacs were not present in the small number of score one capped hocks examined pathologically. It was a proliferation of collagenous connective tissue that gave the point of the hock a swollen appearance. But the fact that the prevalence of capped hock score one in the current study was associated with the environment, suggests that if this lesion was a misclassification, it was not occurring randomly. It is possible that the proliferation of tissue at the point of the hock might be a precursor to the development of bursal sacs which were present in the score two and three capped hock lesions. It is also possible that body fat and therefore the fattiness of the hocks, was correlated with floor type.

This study illustrated that the risk of limb lesions was minimal in pigs housed on soil with deep straw bedding. Calluses, bursitis and capped hock are a pathological response to housing on hard, unbedded floors. If the prevalence of slatted floors in commercial pig farms in England continues to increase, the prevalence and severity of these lesions is also likely to increase. Although calluses, bursitis and capped hock were associated with floor type in a similar manner, differences in the pattern of association between the lesions suggested differing aetiology.

The risk of calluses increased as the quantity of bedding on the floor reduced. However, the proportion of the pen that was slatted was not significantly associated with the prevalence of calluses, indicating that voids in the surface did not increases the risk in addition to lack of bedding. In contrast, the risk of bursitis and capped hock (score two and three) increased as both the quantity of bedding on the floor reduced, making the floor harder, and the proportion of the floor that was slatted increased, reducing the weight bearing surface area.

Among pigs on slatted floors, the lowest risk of bursitis might have occurred on concrete slats because they provided a larger area for weight bearing than metal or plastic slats (Chapter 2, Table 2.12). It is unclear why concrete slats were associated with an increased risk of all scores of capped hock.

Pigs that were dirty may have been less likely to have calluses because the dirt protects the skin or creates a soft layer on the floor. However, it might also be that the lower prevalence of calluses in pens of dirty pigs occurred because calluses were not detected when covered with dirt. To investigate this, all pigs' limbs would have had to have been cleaned before examination. In this large cross sectional study time constraints meant that this was not feasible. The cleanliness of the pig was also associated with the floor type, use of bedding and the slat material (Chapter 2, Table 2.18), however these were controlled for in the model when the effect was detected.

It has been proposed that pigmented pigs (Hampshire, Duroc or Meishan in their breed line) might have a reduced risk of bursitis because they have thicker skin (Smith and Morgan, 1994) or thicker subcutaneous fat on the limbs (Penny and Hill, 1974; Smith and Morgan, 1994). However, these results must be treated with caution because it is possible that breed line is correlated with a management or housing variable that has not been controlled for in the models. Under experimental conditions, no difference in the prevalence of bursitis between pigmented and non pigmented breeds of pig was detected (Guy *et al.*, 2002).

The higher prevalence of capped hock and bursitis in older pigs might occur because they have been housed on hard floors for longer, or due to increased time spent lying down per day (Ekkel *et al.*, 2003) or because as pigs grow their limbs support more weight when lying per weight bearing surface area (Arey, 1993). A similar pattern was reported by Mouttotou *et al.* (1999b). Although it has been reported that bursal swellings can resolve (Kelly *et al.*, 2000) the increase in prevalence with age may also be an indication that some of these lesions become chronic and therefore prevalence accumulates over time. The lack of association between calluses and age might indicate that these lesions can develop and resolve during a pig's life and that increasing body weight does not increase the risk.

Although this study does indicate that the risks for capped hock and bursitis differ, the suggestion by Mouttotou *et al.* (1999b) that capped hock is an injury caused by slipping and knocking the hock joint is not supported by the results; in contrast bursitis appears to be associated with damaged or slippery floors. The fact that capped hock and bursitis were positively correlated, but did not have identical risks, also suggests that Smith's hypothesis (1993), that individual choice of posture determines whether a pig develops capped hock or bursitis, is unlikely. In the current study significant associations between calluses and bursitis and capped hock were also detected. However, these results must be interpreted with caution, as due to the large sample size, variables that are only weakly correlated return a statistically significant result. For example, despite the statistically significant association, the prevalence of bursitis explains less than 1% of the variation in the prevalence of calluses and therefore is of limited biological significance.

3.4.1 Conclusions

Calluses, bursitis and capped hock are highly prevalent in post weaning pigs. They develop in response to hard and slatted indoor floors. The histological examination of bursae and capped hock indicated they were unlikely to be painful, at least after the initial trauma. However, limb lesions may provide an indication of the degree of physiological adaptation necessitated by the floor for the pig to cope with its environment. While there were some differences in the patterns of risk between the three lesions, this study provides evidence that the prevalence of calluses, bursitis and capped hock would be reduced if pigs were housed on soil or provided with deep bedding.

Chapter 4

Limb lesions in gilts and pregnant sows

4.1 Introduction

The prevalence and risks associated with limb lesions in post weaning pigs have been well documented (Chapter 3). There is much less information regarding the prevalence of, and risks for, limb lesions in gilts and sows. von Berner *et al.* (1990) examined 270 pregnant sows from two farms and reported that the overall prevalence of bursitis was 53%. The prevalence of bursitis was higher in sows housed on cast iron slats (60%) compared with sows housed on solid concrete floors (41%) (von Berner *et al.*, 1990). Leeb *et al.* (2001) reported 90% of 1177 loose housed pregnant sows from 55 Austrian farms had calluses on the limbs and body. Leeb *et al.* (2001) reported that there were significantly more calluses when the sows were housed without bedding than when bedding was present in the lying area or in the whole pen.

In this chapter the prevalence, associated risks and population attributable fractions for calluses, bursitis and capped hock in maiden gilts, pregnant gilts and pregnant sows are presented.

4.2 Materials and methods

4.2.1 Data collected

On each farm three pens, or paddocks, were randomly selected; one each of maiden gilts, pregnant gilts and pregnant sows. All four limbs of up to ten pigs from each pen or paddock were examined for calluses, bursitis and capped hock (Chapter 2, Table 2.3). The floor construction and the condition of the environment was also recorded (Chapter 2, Table 2.7). The housing risks associated with the prevalence of limb lesions were investigated in binomial logistic and multinomial multilevel models (Chapter 2, section 2.13)

4.2.2 Sample of pigs

A total of 2,411 pigs were examined; 801 maiden gilts, 744 pregnant gilts and 866 pregnant sows, 413 were housed outdoors and 1,998 were housed indoors. Prevalence was calculated in 2,086 pigs from the ABP English farms for which there was complete data.

4.3 Results

4.3.1 Prevalence of limb lesions in 2,086 gilts and pregnant sows

The prevalence of calluses, bursitis and capped hock in 2,086 gilts and pregnant sows was 43.0%, 30.7% and 37.1% respectively. The prevalence and size of lesions varied between maiden gilts, pregnant gilts and pregnant sows (Table 4.1). There was an increased risk of capped hock (OR 1.9, CI 1.4, 2.5) and calluses (OR 1.8, CI 1.3, 2.4) in pregnant sows compared with maiden gilts.

Table 4.1: Number and percent of maiden gilts, pregnant gilts and pregnant sows with limb lesions score 0 – 3

		Maiden gilts		Pregnant gilts		Pregnant sows	
Lesion	Score	n	%	n	%	n	%
Calluses	Score 0	492	69.6	418	65.5	364	49.1
	Score 1	156	22.1	158	24.8	144	19.4
	Score 2	55	7.8	57	8.9	163	22.0
	Score 3	4	0.6	5	0.8	70	9.4
Total affected score 1 -3		215	30.4	220	34.5	337	50.9
Bursitis	Score 0	481	68.0	463	72.6	501	67.6
	Score 1	126	17.8	118	18.5	120	16.2
	Score 2	83	11.7	52	8.2	106	14.3
	Score 3	17	2.4	5	0.8	14	1.9
Total affected score 1 -3		226	32.0	175	27.4	240	32.4
Capped hock	Score 0	406	67.6	308	63.1	401	54.1
	Score 1	141	23.5	127	26.0	195	26.3
	Score 2	51	8.5	49	10.0	129	17.4
	Score 3	3	0.5	4	0.8	16	2.2
Total affected score 1 -3		195	32.4	180	36.9	340	45.9
Total n		707		638		741	

As in post weaning pigs (Chapter 3), calluses were more prevalent on the fore limbs while bursae were more prevalent on the hind limbs (Table 4.2). Bursae occurred on the fore limbs approximately twice as frequently in pregnant sows than in maiden or pregnant gilts. The prevalence of lesions was similar on the right and left limbs (Table 4.2).

The prevalence of lesions varied by paddock condition in gilts and sows housed outdoors (Table 4.3) and floor type and floor condition in gilts and sows housed indoors (Table 4.4).

Table 4.2: Number and percent of maiden gilts, pregnant gilts and pregnant sows with limb lesions by limb and score

		Maiden gilt		Pregnant gilt		Pregnant sow	
		n	%	n	%	n	%
Calluses	Fore right	210	29.7	224	35.1	339	45.7
	Fore left	210	29.7	222	34.8	326	44.0
	Hind right	59	8.3	57	8.9	112	15.1
	Hind left	58	8.2	61	9.6	114	15.4
Bursitis	Fore right	41	5.8	27	4.2	79	10.7
	Fore left	41	5.8	28	4.4	77	10.4
	Hind right	161	22.8	121	19.0	142	19.2
	Hind left	163	23.1	128	20.1	139	18.8
Capped hock	Hind right	200	28.3	208	32.6	326	44.0
	Hind left	207	29.3	208	32.6	326	44.0
Total n		707		638		741	

Table 4.3: Number and percent of gilts and pregnant sows with limb lesions by ground condition

	Calluses		Bursitis		Capped hock		Total
	n	%	n	%	n	%	n
Grass cover							
None	13	7.5	17	9.8	44	25.3	174
<25%	6	9.5	10	15.9	11	17.5	63
25-50%	3	4.5	9	13.4	5	7.5	67
>50%	1	2.1	0	0.0	8	17.0	47
Surface stones							
None	0	0.0	2	8.0	5	20.0	25
<25%	11	6.0	14	7.7	36	19.8	182
25-50%	10	11.6	14	16.3	23	26.7	86
>50%	2	3.4	6	10.3	4	6.9	58
Ruts and holes							
None	2	5.0	3	7.5	10	25.0	40
<25%	3	1.5	9	4.6	39	19.9	196
25-50%	18	18.8	21	21.9	17	17.7	96
>50%	0	0.0	3	15.8	2	10.5	19
Wet mud							
None	2	3.0	5	7.5	9	13.4	67
<25%	10	8.3	9	7.5	23	19.2	120
25-50%	10	14.7	11	16.2	21	30.9	68
>50%	1	1.0	11	11.5	15	15.6	96
Slope							
Flat	9	6.4	11	7.9	39	27.9	140
Just sloping	10	6.1	13	8.0	22	13.5	163
Medium slope	4	10.3	12	30.8	7	17.9	39
Severe slope	0	0.0	0	0.0	0	0.0	9

Table 4.4: Number and percent of gilts and pregnant sows with limb lesions by breed line, floor type and condition

	Gilts							Pregnant sows						
	Calluses		Bursitis		Capped hock		Total	Calluses		Bursitis		Capped hock		Total
	n	%	n	%	n	%	n	n	%	n	%	n	%	n
Pregnancy status														
Maiden gilts	262	38.7	220	32.5	207	30.6	677							
Pregnant gilts	251	41.1	173	28.4	214	35.1	610							
Floor type														
Solid deep bedding all areas	103	39.8	73	28.2	79	30.5	259	71	56.8	36	28.8	67	53.6	125
Solid deep / sparse bedding all areas	148	52.1	119	41.9	107	37.7	284	167	66.3	111	44.0	112	44.4	252
Solid sparse bedding all areas	104	54.5	71	37.2	79	41.4	191	37	59.7	25	40.3	35	56.5	62
Solid deep bedding in the lying area	38	35.2	35	32.4	39	36.1	108	32	54.2	10	16.9	26	44.1	59
Solid sparse bedding in the lying area	25	48.1	12	23.1	25	48.1	52	31	64.6	15	31.3	29	60.4	48
Partly or fully slatted	74	69.8	47	44.3	37	34.9	106	39	78.0	24	48.0	21	42.0	50
Outdoor	15	5.9	31	12.3	44	17.4	253	9	7.1	13	10.3	35	27.8	126
Breed line														
Non pigmented	381	46.8	285	35.0	297	36.5	814	249	54.1	173	37.6	214	46.5	460
Pigmented	116	25.6	92	20.3	113	24.9	453	110	49.1	55	24.6	91	40.6	224
Pigs observed slipping														
Yes	251	35.6	164	23.3	204	28.9	705	206	45.4	118	26.0	198	43.6	454
No	212	49.8	192	45.1	173	40.6	426	147	69.7	91	43.1	99	46.9	211
Wet slurry in the lying area														
No	430	47.8	332	36.9	323	35.9	900	316	65.7	175	36.4	234	48.6	481
Yes	54	54.5	22	22.2	46	46.5	99	49	47.1	37	35.6	50	48.1	104
Wet floor in the dunging area														
Yes	150	43.6	99	28.8	106	30.8	344	157	77.0	75	36.8	115	56.4	204
No	338	50.1	259	38.4	268	39.7	675	219	55.9	144	36.7	178	45.4	392
Dry slurry on the floor in the dunging area														
Yes	435	48.7	309	34.6	335	37.5	893	327	64.2	193	37.9	266	52.3	509
No	53	42.1	49	38.9	39	31.0	126	49	56.3	26	29.9	27	31.0	87

4.3.2 Risks associated with limb lesions in maiden and pregnant gilts

4.3.2.1 Calluses

There was a reduced risk of calluses in outdoor housed gilts compared with indoor housed gilts (OR 0.07, CI 0.03, 0.14). In indoor housed gilts there was an increased risk of calluses in gilts housed on slatted floors (fully and partly slatted with and without bedding) compared with solid concrete floors with deep bedding in all areas. There was a reduced risk of calluses in pens with dry slurry on the floor in the dunging area compared with pens with a clean floor (Table 4.5).

4.3.2.2 Bursitis

There was a reduced risk of bursitis in outdoor housed gilts compared with indoor housed gilts (OR 0.2, CI 0.1, 0.4). In contrast to the results for post weaning pigs (Chapter 3), in indoor housed gilts the prevalence of bursitis did not differ significantly by floor type. There were non significant trends for increased risk of bursitis where pigs had been observed slipping on the floor and a reduced risk of bursitis in pigmented pigs compared with non pigmented pigs (Table 4.5).

4.3.2.3 Capped hock

4.3.2.3.1 Logistic regression

There was a reduced risk of capped hock in outdoor housed gilts compared with indoor housed gilts (OR 0.4, CI 0.2, 0.7). In indoor housed gilts the prevalence of capped hock did not differ significantly by floor type (Table 4.5).

4.3.2.3.2 Multinomial regression

There was no significant association between the prevalence of capped hock score one and floor type. The risk of capped hock score two / three increased as the quantity of bedding on the floors decreased, compared with solid concrete floors with deep bedding in all areas (Table 4.6).

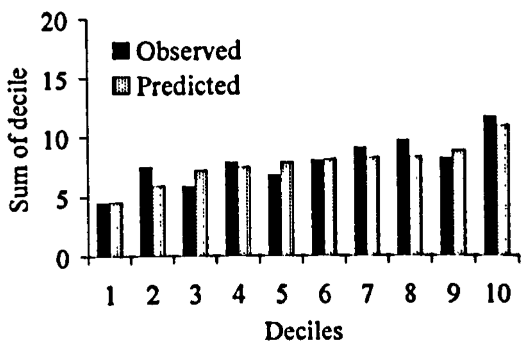
4.3.2.4 Model fit and observer differences

The Hosmer-Lemeshow goodness-of-fit test indicated that the differences between the observed and predicted values for limb lesions in gilts were very small (Table 4.5 and Figure 4.1). It is likely that the predicted proportion affected was similar to the observed proportion because there was little variation in the prevalence of affected pigs and because the random effects of farm and pen explained a large proportion of the variation.

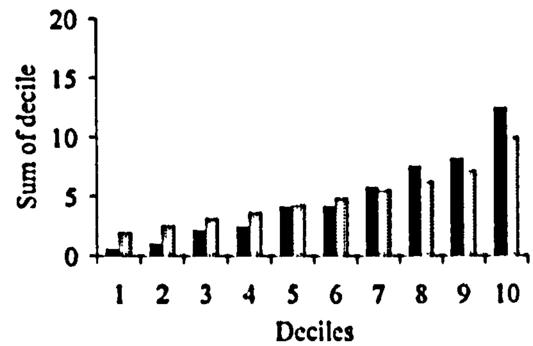
Controlling for the identity of the observer did not alter the model for capped hock. However, when observer was added to the callus model, dry slurry in the dunging area became non significant and when observer was added to the bursitis model pigmented pigs were no longer associated with a lower risk of bursitis.

Figure 4.1: Graphs a-c of observed verses predicted values from logistic binomial regression models of limb lesions in gilts

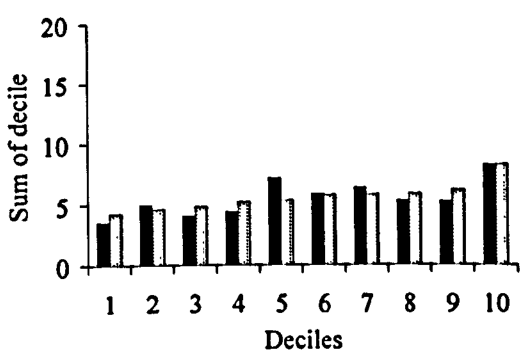
a. Calluses



b. Bursitis



c. Capped hock



4.3.3 Risks associated with limb lesions in pregnant sows

4.3.3.1 Calluses

There was a reduced risk of calluses in pregnant sows housed outdoors compared with pregnant sows housed indoors (OR 0.05, CI 0.02, 0.12). The risk of calluses did not differ significantly with the floor the pig was housed on.

Table 4.5: Multilevel logistic binomial models of risks associated with limb lesions in gilts and pregnant sows

	Gilts						Pregnant sows					
	Calluses n = 152 pens		Bursitis n = 132 pens		Capped hock n = 153 pens		Calluses n = 644 pigs		Bursitis n = 681 pigs		Capped hock n = 677 pigs	
Intercept coefficient	-0.3		-0.4		-1.2		-1.1		-0.9		-1.2	
	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI
Pregnancy status												
Maiden gilts	1.0		1.0		1.0							
Pregnant gilts†	1.2	0.9, 1.6	0.8	0.6, 1.2	1.4	1.05, 1.78						
Body condition score											1.6	1.1, 2.3
Floor type												
Solid deep bedding all areas	1.0		1.0		1.0		1.0		1.0		1.0	
Solid deep / sparse bedding all areas	1.3	0.7, 2.4	1.1	0.5, 1.8	1.2	0.7, 1.9	1.6	0.7, 4.0	1.7	0.8, 3.4	0.6	0.3, 1.3
Solid sparse bedding all areas	1.3	0.7, 2.4	1.4	0.7, 2.6	1.6	0.9, 2.7	2.2	0.6, 7.3	1.6	0.6, 4.2	1.1	0.4, 2.9
Solid deep bedding in lying area	0.5	0.2, 1.1	0.8	0.3, 2.0	1.2	0.6, 2.6	1.4	0.4, 4.9	0.7	0.2, 1.9	0.5	0.2, 1.5
Solid sparse bedding in lying area	1.3	0.5, 3.6	0.8	0.3, 2.2	1.6	0.7, 4.0	1.8	0.4, 7.3	1.1	0.3, 3.4	1.2	0.4, 3.7
Partly or fully slatted	4.0	2.4, 6.9	1.2	0.5, 2.8	1.4	0.7, 2.9	2.2	0.6, 8.8	2.1	0.7, 6.1	0.6	0.2, 1.7
Breed line												
Non pigmented			1.0									
Pigmented			0.6	0.4, 1.1								
Pigs observed slipping												
No			1.0									
Yes			1.5	1.0, 2.3								
Floor condition*												
Wet slurry on floor in lying area							0.3	0.1, 0.9				
Wet floor in the dunging area							0.3	0.1, 0.6				
Dry slurry on floor in dunging area	0.5	0.3, 0.9										
Random effect	Var.	SE	Var.	SE	Var.	SE	Var.	SE	Var.	SE	Var.	SE
Farm	1.4	0.3	0.5	0.2	0.9	0.2	1.3	0.3	0.8	0.2	0.8	0.2
Pen	0.0	0.0	0.2	0.2	0.0	0.0						
Hosmer-Lemeshow goodness-of-fit	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
	0.6	0.99	1.2	0.96	0.5	0.99	11.6	<0.05	7.3	0.20	19.5	<0.05

* compared with pigs housed on floors where these conditions were not observed, † CI presented to two decimals places where it affects p value

Table 4.6: Multilevel multinomial models of the risks associated with capped hock score one and score two or three in gilts and pregnant sows

	Gilts n = 1159				Pregnant sows n = 677			
	Score 1		Score 2 / 3		Score 1		Score 2 / 3	
Intercept coefficient	-1.5		-2.9		-0.7		-0.3	
	OR	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Pregnancy status								
Maiden gilts	1.0		1.0					
Pregnant gilts	1.3	1.0, 1.7	1.7	1.1, 2.5				
Body condition score								
≤2					1.0		1.0	
2.5					1.2	0.4, 3.8	0.8	0.3, 2.6
3					1.8	0.6, 4.8	1.1	0.4, 2.9
3.5					1.9	0.7, 5.5	1.1	0.4, 3.3
4					3.3	1.0, 11.0	1.9	0.5, 6.6
Floor type								
Solid deep bedding all areas	1.0		1.0		1.0		1.0	
Solid deep / sparse bedding all areas	1.2	0.8, 1.8	1.1	0.6, 2.2	0.7	0.4, 1.2	0.5	0.3, 0.9
Solid sparse bedding all areas	1.6	1.0, 2.7	1.4	0.7, 2.9	1.3	0.6, 3.0	0.8	0.3, 1.9
Solid deep bedding in lying area	1.0	0.5, 2.0	1.9	0.8, 4.7	0.6	0.2, 1.3	0.5	0.2, 1.2
Solid sparse bedding in lying area	0.9	0.4, 2.3	3.2	1.2, 8.8	1.1	0.4, 2.7	0.7	0.3, 2.0
Partly or fully slatted	1.0	0.5, 2.0	3.0	1.3, 6.9	0.8	0.3, 2.0	0.4	0.1, 2.1
Random effect	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**
Farm	0.6	0.1	0.9	0.3	1.8	0.3	2.0	0.4
Covariance between scores	0.5	0.1			0.2	0.1		

There was a reduced risk of calluses when there was wet slurry on the floor in the lying area and a wet dunging area, compared with dry clean floors (Table 4.5).

4.3.3.2 *Bursitis*

There was a reduced risk of bursitis in pregnant sows housed outdoors compared with pregnant sows housed indoors (OR 0.3, CI 0.1, 0.6). In indoor housed pregnant sows the prevalence of bursitis did not differ significantly by floor type.

However, there was a non significant trend for increased prevalence on slatted floors compared with solid concrete floors with deep bedding (Table 4.5).

4.3.3.3 Capped hock

4.3.3.3.1 Logistic regression

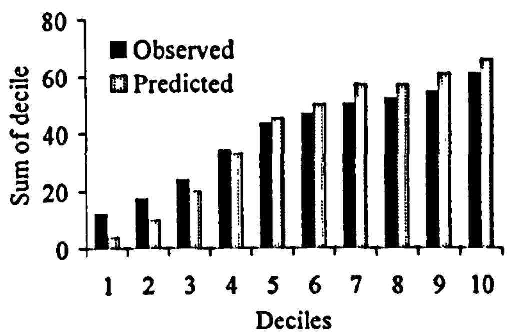
There was a reduced risk of capped hock in outdoor housed pregnant sows compared with indoor housed pregnant sows (OR 0.3, CI 0.2, 0.7). There were no significant differences in the risk of capped hock associated with indoor floor type. In indoor housed pregnant sows there was an increased risk of capped hock associated with increasing body condition score (Table 4.5).

4.3.3.3.2 Multinomial regression

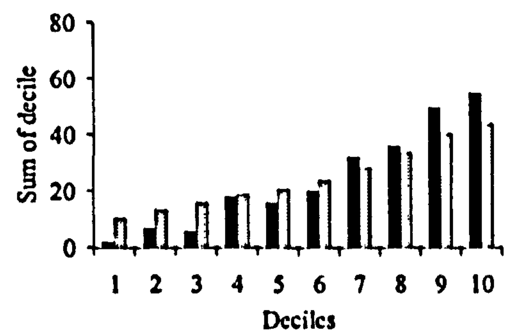
There was no association between floor type and the risk of capped hock score one or capped hock score two / three. There was a trend for increased risk of capped hock score one and capped hock score two / three in sows with higher body condition (Table 4.6).

Figure 4.2: Graphs a-c of observed verses predicted values from logistic binomial regression models of limb lesions in pregnant sows

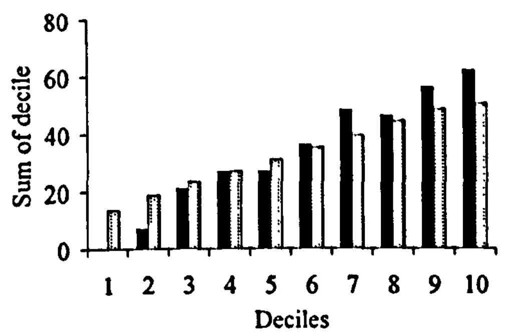
a. Calluses



b. Bursitis



c. Capped hock



4.3.3.4 Model fit and observer differences

In pregnant sows, variables at the level of the pig, i.e., body condition, was significantly associated with the prevalence of limb lesions. Therefore, a binary pig level outcome was used in the models. Accurately predicting the outcome for individual pigs is more difficult than predicting the proportion affected and this is reflected in the large chi squared values of the Hosmer-Lemeshow goodness-of-fit statistic for the pregnant sow models (Table 4.5). However, the graphs of observed verses predicted values illustrated that the observed values broadly increased with the predicted values (Figure 4.2).

When identity of the observer was controlled for in the model the fixed effects for capped hock did not differ. However, with calluses and bursitis, the risk associated with housing on slatted floors increased.

4.3.4 Associations between paddock conditions and the risk of limb lesions

There was no significant effect of grass cover, stones on the surface, ruts and holes, wet mud or gradient of the paddock on the prevalence of calluses, bursitis and capped hock in outdoor housed gilts and pregnant sows (data not shown).

4.3.5 Population attributable fractions of limb lesions in gilts and pregnant sows

Assuming a causal relationship, the prevalence of limb lesions would be reduced by between 38% and 86% depending on lesion type if gilts and sows currently housed indoors were housed outdoors. The largest proportion of limb lesions in pregnant sows and gilts was attributable to solid concrete floors with deep / sparse bedding and the next greatest proportion to solid floors with sparse bedding in all areas (Table 4.7).

Table 4.7: Population attributable fractions of limb lesions in gilts and pregnant sows

	Gilts n = 1252 gilts			Pregnant sows n = 722 sows		
	Calluses	Bursitis	Capped hock	Calluses	Bursitis	Capped hock
Outdoor	0.0	0.0	0.0	0.0	0.0	0.0
Solid deep bedding all areas	17.3	10.6	8.3	15.9	9.8	9.9
Solid deep / sparse bedding all areas	25.9	21.7	14.1	38.3	35.9	12.9
Solid sparse bedding all areas	18.3	12.3	11.2	8.4	7.9	5.5
Solid deep bedding in lying area	6.2	5.6	4.9	7.1	1.7	3.0
Solid sparse bedding in lying area	4.3	1.5	3.9	7.1	4.2	4.8
Partly or fully slatted	3.4	8.8	4.5	9.1	8.0	2.2
Total reduction	85.4	60.4	46.9	85.9	67.4	38.3

4.3.6 Associations between calluses, bursitis and capped hock in gilts and pregnant sows

As in post weaning pigs (Chapter 3), calluses were positively correlated with bursitis ($r = 0.15$, $df = 2336$, $p < 0.05$) and capped hock ($r = 0.19$, $df = 2336$, $p < 0.05$) within gilts and pregnant sows. However, in contrast to post weaning pigs, there was no association between capped hock and bursitis ($r < -0.01$, $df = 2336$, $p > 0.05$). The data categorised by maiden gilts, pregnant gilts and pregnant sows produced similar correlations (data not shown).

4.4 Discussion

This study provides the first estimates for the prevalence of limb lesions in gilts and pregnant sows on a cross section of commercial English farms. As reported in post weaning pigs (Chapter 3), gilts and pregnant sows had the lowest prevalence of limb lesions when housed outdoors. It is likely that the yielding, supportive properties of soil and the fact that deep bedding was provided in the huts, is associated with the reduced prevalence of limb lesions. In the current study, although prevalence of limb lesions varied with paddock conditions, no significant associations were detected. It might be that the pigs spent little time lying outside the huts. Or that the current study lacked sufficient power to detect an affect as the sample of outdoor housed gilts and sows was relatively small.

As with post weaning pigs (Chapter 3), gilts housed on slatted floors had an increased risk of calluses, probably due to kneeling and lying on hard unbedded surfaces. However, few gilts and pregnant sows were housed on these floors; over 90% were housed on solid floors with bedding. This is likely to have a positive impact on the welfare of these sows and gilts as bedding provides a soft lying surface, dietary bulk and a manipulatable substrate for rooting (Arey, 1993). But the low prevalence of slatted floors made it difficult to analyse the impact of these floors on the prevalence of limb lesions in gilts and sows. In addition the 'slatted' category contained fully slatted floors and partly slatted floors with and without bedding. This may explain why slatted floors were not associated with a significant increase in risk of calluses in pregnant sows, because if bedding is provided in the lying area in a partly slatted pen sows may spend little time kneeling or lying on the unbedded slatted area. In post weaning pigs the lack of bedding was the key risk, rather than the proportion of the pen that was slatted.

Post weaning pigs that were dirty had a lower prevalence of calluses, perhaps because the calluses were harder to identify or because dirt softened the floor surface (Chapter 3). It is probable that pregnant sows and gilts in pens with wet and dirty floors had a reduced prevalence of calluses for similar reasons but the aetiology remains unclear.

In common with post weaning pigs, there was a trend for an increased risk of bursitis associated with floors on which pigs were seen slipping. There was also an indication that pigs with Hampshire, Duroc or Meishan in their breed line had less bursitis, perhaps due to a thicker skin or subcutaneous fat layer (Penny and Hill, 1974).

The risk of capped hock score two / three in gilts increased as the quantity of bedding on the floor reduced and prevalence was highest on slatted floors, in a similar pattern to post weaning pigs. However, capped hock score one was not associated with floor type. It remains unclear whether gilts with capped hock score one were affected, or whether these pigs were misclassified. The risk of capped hock increased with body condition in pregnant sows, yet body condition was not associated with the prevalence of capped hock in gilts. Body condition may have been acting as a measure of age, because older sows tend to have higher body condition (Chapter 5). Alternatively sows with higher body condition might be at an increased risk of capped hock because of the greater weight on the limbs when lying, because they spent more time lying or because fatty tissue on the hocks was misclassified as capped hock.

There are several possible reasons why floor type was not associated with capped hock and bursitis in sows and gilts in the same way as for post weaning pigs. It may be that the lesions observed on the limbs are chronic and did not develop while the pigs were housed on the floor type they were on at the time of observation. This is one of the problems of examining older pigs in a cross sectional study, little is known about the history of the pig. In sow yards, where new pigs were added each week, it was not known how long the pig had been on the current floor or the floor they had been housed on during the previous lactation, because farms commonly had more than one floor type in their farrowing pens. It is also possible that older pigs are less susceptible to developing capped hock and bursitis than grower and finisher pigs.

Similar patterns of prevalence of lesions by limb were observed in post weaning pigs, gilts and pregnant sows. Calluses are probably more prevalent on the fore limbs because a pig kneels on the carpal joints when in transition between standing and lying. The higher prevalence of bursitis on the hind limbs may occur because they support more weight when the pig is lying or dog sitting or because hind limbs are more likely to contact with the floor and be injured when a pig slips. The prevalence of bursitis on the fore limbs was higher in pregnant sows than post weaning pigs and gilts. Perhaps due to the larger body weight placing extra pressure on the fore limbs when lying.

4.4.1 Conclusions

There was some agreement between the patterns of prevalence of limb lesions for post weaning pigs, gilts and pregnant sows; in all cases the lowest prevalence occurred in outdoor housed pigs and there was a trend for increased risk of bursitis in non pigmented pigs and pigs housed on slippery floors. However, indoors hard and slatted floors were not associated with an increased prevalence of capped hock and bursitis in gilts and pregnant sows as in post weaning pigs. It is possible that some of these lesions are chronic and therefore in older animals may not be associated with the current floor type.

Chapter 5

Limb and body lesions in lactating sows

5.1 Introduction

Pigs housed outdoors during farrowing and lactation have greater freedom than sows in standard indoor production. Outdoors, sows are able to select a hut in which to build a farrowing nest and have the freedom to leave the hut as they choose to use a separate area for dunging. In indoor production, the widespread use of farrowing crates restricts these freedoms and the farrowing pen floor must, as far as possible, meet all the sow's needs for a comfortable lying surface, a non slip standing surface and separation from waste products.

To meet these requirements and minimise labour, farrowing pen floors are often slatted and have little or no bedding (Chapter 2). This, combined with the lack of mobility, and therefore the large proportion of time spent lying, means that lactation is likely to be a high risk period for the development of lesions on the limbs and body of sows. The type of floor and floor material in farrowing pens has been reported to be associated with the risk of lesions. Edwards and Lightfoot (1986) compared the prevalence of limb lesions in 383 lactating sows housed on an experimental unit with solid concrete floors and partly or fully slatted floors of punched metal or plastic coated woven wire. The lowest prevalence of wounds on the limbs occurred on solid concrete floors and the prevalence increased as the proportion of the pen that was slatted increased. In both partly and fully slatted pens there was a higher prevalence of wounds in sows housed on plastic coated woven wire flooring compared with punched metal floors (Edwards and Lightfoot, 1986). Davies *et al.* (1996) also noted an increased prevalence of body lesions on a farm where pigs were housed on woven wire flooring and proposed that the high percentage void was a contributing factor. This was confirmed by Bonde *et al.* (2003) who reported an increased risk of shoulder lesions associated with slatted floors in 555 lactating sows from 10 commercial herds in Denmark. As discussed in Chapter 4, slatted floors and lack of bedding have also been reported to be associated with increased prevalence of bursitis (von Berner *et al.*, 1990) and calluses (Leeb *et al.*, 2001) in pregnant sows. Published results on the prevalence of these lesions in lactating sows is not available.

An increased risk of body lesions has been associated with prolonged periods of recumbency around parturition (Davies *et al.*, 1997), small farrowing crates (Curtis *et al.*, 1989), poor body condition (Davies *et al.*, 1996; Bonde *et al.*, 2004; Zurbrigg, 2006; Karlen *et al*, 2007; Knauer *et al.*, 2007) and wet skin (Davies *et al.*, 1996; Zurbrigg, 2006).

In this chapter the prevalence, associations with floor type and pen environment and the population attributable fraction for limb and body lesions in lactating sows are presented.

5.2 Materials and methods

5.2.1 Data collected

On each farm, four lactating sows, one each of 3 – 7, 8 – 14, 15 – 21 and 22 – 28 days post partum, were randomly selected. The sow's body and all four limbs were examined. Lesions were classified and their location and severity were recorded (Chapter 2, Table 2.3 and Table 2.5). The sow's body condition was scored 1 – 5 allowing for half points according to the guidelines provided by DEFRA.

Data were collected on the floor type, the condition of the floor and the use of bedding (Chapter 2, Table 2.7). The risks associated with the prevalence of limb and body lesions were investigated in multilevel binomial and logistic multivariable models (Chapter 2, 2.13 for more detail)

5.2.2 Sample of lactating sows

A total of 339 sows were examined; 289 housed indoors in farrowing crates and 50 housed outdoors. Prevalence was calculated in sows from the ABP English farms for which there was complete data; 279 for limb lesions and 288 sows for body lesions. Sows from an additional nine convenience selected farms were included in the risk factor analysis. The number of pigs included in each analysis is listed in each table.

5.3 Results

5.3.1 Prevalence of limb lesions in 279 lactating sows

The prevalence of wounds, calluses, bursitis and capped hock on the limbs of 279 sows was 18.3%, 84.9%, 36.9% and 57.0% respectively. Wounds and bursitis were more prevalent on the hind limbs while calluses were more prevalent on the fore limbs. The prevalence of lesions on the right and left limbs was very similar (Table 5.1). The modal maximum lesion score for calluses and bursitis was two and for wounds and capped hock was one (Table 5.1).

Table 5.1: Number and percent of 279 lactating sows with limb lesions by limb and score

	Wounds		Calluses		Bursitis		Capped hock	
	n	%	n	%	n	%	n	%
Limb								
Fore right	18	6.5	222	79.6	31	11.1		
Fore left	19	6.8	225	80.6	26	9.3		
Hind right	23	8.2	68	24.4	66	23.7	150	53.8
Hind left	24	8.6	68	24.4	57	20.4	149	53.4
Score								
Score 0	228	81.8	42	15.0	176	63.1	120	43.0
Score 1	35	12.5	48	17.2	44	15.8	90	32.3
Score 2	14	5.0	102	36.6	45	16.1	60	21.5
Score 3	2	0.7	87	31.2	14	5.0	9	3.2

5.3.1.1 Comparing prevalence of limb lesions in 279 lactating and 741 pregnant sows

There was a significantly higher prevalence of calluses (difference in prevalence; 34%, $\chi^2 = 111.8$, df =1, $p < 0.001$) and capped hock (difference in prevalence; 11.1%, $\chi^2 = 10.0$, df = 1, $p < 0.01$) in indoor and outdoor housed lactating sows compared with the pregnant sows (Chapter 4). There was a higher prevalence of bursitis in lactating sows (36.9%) compared with pregnant sows (30.7%) ($p > 0.05$).

5.3.2 Prevalence of body lesions in 288 lactating sows

The prevalence of scars and new body lesions, in 288 indoor and outdoor housed sows was 35.4%; 17.7% of sows had scars and 19.8% had new lesions. The prevalence of new lesions on the shoulders was 10.4% and the prevalence elsewhere on the body (hip, spine or tail area) was 11.7% (Table 5.2). On the shoulder new ($\chi^2 = 8.3$, df = 1, $p < 0.01$) lesions were more likely to be bilateral than by chance.

Table 5.2: Number and percent of 288 sows with new body lesions and body scars by location

		New		Scars		Any lesion	
		n	%	n	%	n	%
Shoulder	Left	22	7.6	17	5.9	37	12.8
	Right	21	7.3	17	5.6	37	12.8
	Bilateral	13	4.5	6	2.1		
Hip	Left	3	1.0	5	1.7	8	2.8
	Right	2	0.7	5	1.7	7	2.4
	Bilateral	1	0.3	2	0.7		
Tail		22	7.6	10	3.5	32	11.1
Spine		12	4.2	13	4.5	25	8.7
Hip, tail and spine total		33	11.4	28	9.7	60	20.8

Body lesions at all locations were more prevalent and larger in sows housed indoors compared with sows housed outdoors (Table 5.3). The majority of lesions in sows housed outdoors were old lesions, only one of the 39 sows housed outdoors had a new body sore.

Table 5.3: Percent of 288 indoor and outdoor housed lactating sows with new and old body lesions score 0-3 by location

	Shoulders		**Hips**		**Tail**		**Spine**	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
Score 0	78.7	94.9	96.0	94.9	87.6	97.4	90.0	100.0
Score 1	13.3	2.6	2.4	2.6	9.2	0.0	7.6	0.0
Score 2	7.2	2.6	1.2	0.0	2.4	2.6	2.0	0.0
Score 3	0.8	0.0	0.4	2.6	0.8	0.0	0.4	0.0
Total n	249	39	249	39	249	39	249	39

The prevalence of body lesions varied by floor type, floor condition, space in the crate, sow body condition and responsiveness to humans (Table 5.4).

Table 5.4: Number and percent of lactating sows with limb lesions and new body lesions by floor type, week of lactation, responsiveness, space in the crate and slat material

	Limb lesions									New body lesions				
	Wounds		Calluses		Bursitis		Capped hock		Total	Shoulders		Hips, spine, tail		Total
Floor type	n	%	n	%	n	%	n	%	n	n	%	n	%	n
Outdoor	0	0.0	13	37.1	4	11.4	11	31.4	35	1	2.6	0	0.0	39
Solid with bedding	5	14.7	30	88.2	13	38.2	17	50.0	34	2	5.9	5	14.7	34
Partly slatted with bedding	4	7.8	47	92.2	24	47.1	30	58.8	51	8	15.7	4	7.8	51
Partly slatted no bedding	32	25.8	112	90.3	50	40.3	80	64.5	124	13	10.5	16	12.9	124
Fully slatted	10	28.6	35	100.0	12	34.3	21	60.0	35	5	15.6	7	21.9	32
Week of lactation														
1-week	19	26.0	64	87.7	20	27.4	37	50.7	73	15	23.8	11	17.5	63
2-week	17	21.8	65	83.3	26	33.3	44	56.4	78	5	7.4	8	11.8	68
3-week	9	14.1	52	81.3	27	42.2	36	56.3	64	4	7.1	3	5.4	56
4-week	6	9.4	56	87.5	30	46.9	42	65.6	64	4	7.4	10	18.5	54
Sow's responsiveness to humans														
Bright, alert and responsive	28	15.9	141	80.1	57	32.4	100	56.8	176	9	6.2	21	14.5	145
May be dull	17	21.3	76	95.0	33	41.3	45	56.3	80	12	15.4	9	11.5	78
Dull and unresponsive	6	26.1	20	87.0	13	56.5	14	60.9	23	7	38.9	2	11.1	18
Space between sow's back and crate														
<5cm	5	16.1	30	96.8	15	48.4	24	77.4	31	7	22.6	7	22.6	31
5-10cm	15	26.3	50	87.7	21	36.8	35	61.4	57	11	19.6	8	14.3	56
>10cm	27	19.9	125	91.9	55	40.4	82	60.3	136	9	6.7	13	9.6	135
Space between sow's tail and crate														
<10cm	7	20.0	31	88.6	18	51.4	22	62.9	35	8	24.2	9	27.3	33
10 – 20cm	11	17.5	57	90.5	30	47.6	39	61.9	63	7	11.5	6	9.8	61
>20cm	28	23.0	113	92.6	41	33.6	77	63.1	122	12	9.7	13	10.5	124
Slat material														
Metal	23	22.7	90	89.1	50	49.5	56	55.4	101	14	11.2	19	15.2	125
Plastic	20	20.6	92	94.8	32	33.0	65	67.0	97	16	14.7	14	12.8	109
Metal and plastic	3	27.3	11	100	3	27.3	8	72.7	11	2	18.2	0	0.0	11

5.3.3 Risk factors associated with limb lesions in lactating sows

5.3.3.1 Wounds

No wounds on the limbs were observed in outdoor housed lactating sows. In indoor housed sows the risk of wounds on the limbs reduced with increasing week of lactation. There was an increased risk of wounds on the limbs associated with fully slatted floors compared with solid concrete floors with bedding. There was a reduced risk of wounds on the limbs on floors with dry slurry in the sow lying area (Table 5.5).

5.3.3.2 Calluses

There was a reduced risk of calluses in lactating sows housed outdoors compared with sows housed indoors (OR 0.1, CI 0.1, 0.2). There was an increased risk of calluses in indoor pigs housed on partly slatted floors with bedding, partly slatted floors with no bedding and fully slatted floors compared with solid concrete floors with bedding. There was a decreased risk of calluses in sows in crates with 5 – 10cm or more than 10cm between the sows back and the top of the crate compared with sows with less than 5cm (Table 5.5).

Table 5.5: Two level binomial logistic regression models of the risks associated with limb and body lesions in lactating sows housed indoors

	Limb lesions								New body lesions n = 249 sows			
	Wounds n = 267		Calluses n = 255		Bursitis n = 276		Cap. hock n = 268		Shoulders		Hips, spine or tail	
Intercept coefficient	0.3		2.2		1.1		-4.0		0.9		1.2	
	OR	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Week of lactation	0.6	0.4, 0.8	1.3	1.0, 1.8	1.5	1.2, 1.8	1.2	0.9, 1.5	0.7	0.44, 0.99	1.0	0.7, 1.4
Body condition score	0.7	0.4, 1.4	0.6	0.3, 1.2	0.4	0.2, 0.7	1.8	1.0, 3.4	0.5	0.2, 1.3	0.5	0.2, 1.2
Floor/Bedding												
Solid concrete with bedding												
Partly slatted / solid concrete with bedding	1.0	0.2, 4.5	3.9	1.1, 13.4	1.8	0.7, 4.8	1.4	0.4, 4.9	0.9	0.1, 6.1	0.5	0.1, 3.2
Partly slatted / solid concrete no bedding	3.2	0.9, 12.1	4.4	1.4, 13.4	1.2	0.5, 2.8	3.5	1.2, 10.7	1.0	0.2, 5.6	1.3	0.3, 5.9
Fully slatted	5.7	1.2, 26.6	8.9	2.0, 38.6	0.8	0.3, 2.3	3.8	1.0, 14.2	1.7	0.2, 12.3	4.7	0.9, 25.0
Initial response to human presence												
Bright alert and responsive												
May be dull					1.2	0.7, 2.1	2.3	1.2, 4.0	3.4	1.3, 8.6	1.0	0.4, 2.3
Dull and unresponsive					2.7	1.1, 7.0	2.3	0.9, 6.3	4.8	1.2, 19.6	0.7	0.1, 4.0
Space between sow's back and the crate												
<5cm												
5-10cm			0.2	0.1, 0.9								
>10cm			0.2	0.1, 0.8								
Space between sow's tail and the crate												
<10cm												
10-20cm									0.5	0.1, 1.7	0.2	0.1, 0.6
>20cm									0.3	0.08, 0.99	0.2	0.1, 0.7
Dry slurry in the sow lying area												
No												
Yes	0.2	0.0, 0.8					0.2	0.1, 0.6				
Wet slurry in the sow lying area												
No												
Yes									7.1	1.5, 34.1		
Cracked / broken floor in the sow lying area												
No												
Yes									4.7	1.1, 19.5		
Random effects	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**
Variation between farms	0.9	0.4	0.7	0.4	1.1	1.0	0.4	0.3	0.5	0.6	0.6	0.6
Hosmer-Lemeshow goodness-of-fit	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**
	8.1	0.15	1.3	0.93	3.3	0.66	3.8	0.60	1.7	0.92	6.4	0.27

†CI presented to two decimal places where it affects interpretation of the p value

5.3.3.3 *Bursitis*

There was a reduced risk of bursitis associated with sows housed outdoors compared with sows housed indoors (OR 0.2, CI 0.1, 0.6). In sows housed indoors, the risk of bursitis increased with increasing week of lactation and decreased with increasing sow body condition. Sows that were 'dull and unresponsive' to human presence had an increased risk of bursitis compared with sows that were 'bright, alert and responsive' (defined according to Main *et al.*, 2000) (Table 5.5).

5.3.3.4 *Capped hock*

5.3.3.4.1 *Logistic regression*

There was a reduced risk of capped hock associated with sows housed outdoors compared with sows housed indoors (OR 0.1, CI 0.1, 0.6). Indoors, an increased risk of capped hock was associated with partly slatted floors with no bedding and fully slatted floors compared with solid concrete floors with bedding. There was an increased risk of capped hock in sows classified as 'may be dull' compared with sows that were 'bright, alert and responsive'. A reduced risk of capped hock was associated with floors with a covering of dry slurry in the sow lying area (Table 5.5).

5.3.3.4.2 Multinomial regression

The pattern of risk associated with capped hock when lesions score one, two and three were considered separately did not differ from the pattern of risks presented in the logistic analysis with all affected pigs grouped together (Table 5.6). However, due to the reduced power, few factors were statistically significant in the multinomial model.

Table 5.6: A two level multinomial model of the risks associated with capped hock by score in 268 lactating sows

	Score 1		Score 2		Score 3	
Intercept coefficient	-1.0		-3.2		-8.4	
	OR	**CI**	**OR**	**CI**	**OR**	**CI**
Week of lactation	1.0	0.8, 1.2	1.1	0.9, 1.4	2.0	1.1, 3.4
Body condition score	1.4	0.8, 2.5	1.9	1.0, 3.4	3.7	1.1, 12.4
Floor/Bedding						
Solid concrete with bedding						
Part slatted / solid concrete with bedding	0.9	0.3, 2,7	1.2	0.3, 4.1	1.3	0.1, 17.0
Part slatted / solid concrete no bedding	1.4	0.5, 3.5	3.6	1.2, 10.8	2.9	0.3, 28.7
Fully slatted	2.4	0.8, 7.3	5.2	1.5, 18.6	2.2	0.1, 33.7
Initial response to human presence						
Bright alert and responsive						
May be dull	0.5	0.3, 1.0	1.6	0.9, 2.6	0.7	0.2, 2.9
Dull and unresponsive	3.6	1.4, 9.3	7.7	2.6, 17.8	9.2	2.0, 41.9
Dry slurry in the sow lying area*						
No						
Yes	0.9	0.4, 2.0	0.2	0.1, 0.7		
Random effect	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**
Pig	0.4	0.3	0.3	0.3	0.8	0.9
Covariance						
Between scores 1 and 2	-0.4	0.2				
Between scores 1 and 3	0.1	0.4				
Between scores 2 and 3	-0.2	0.4				

* there was insufficient sample size to include this variable in the model for score three lesions

5.3.4 Risk factors associated with body lesions in lactating sows

5.3.4.1 Body lesion scars

There was a positive association between body lesion scars and the parity of the sow (OR 1.2, CI 1.1, 1.4). No other associations were detected between floor type, crate size or sow behaviour and body lesion scars.

5.3.4.2 New shoulder lesions

There was only one outdoor housed sow with a new shoulder lesion, so there were insufficient data to calculate an odds ratio between the prevalence outdoors (2.4%) and indoors (12.1%). Indoors, the risk of new shoulder lesions decreased with increasing week of lactation. The risk of new shoulder lesions reduced as the space between the sow's tail and the back of the crate increased. The risk of new shoulder lesions increased as the responsiveness to human presence decreased. An increased risk of new shoulder lesions was associated with a lying area that was damaged or had a covering of wet slurry compared with clean undamaged floors (Table 5.5).

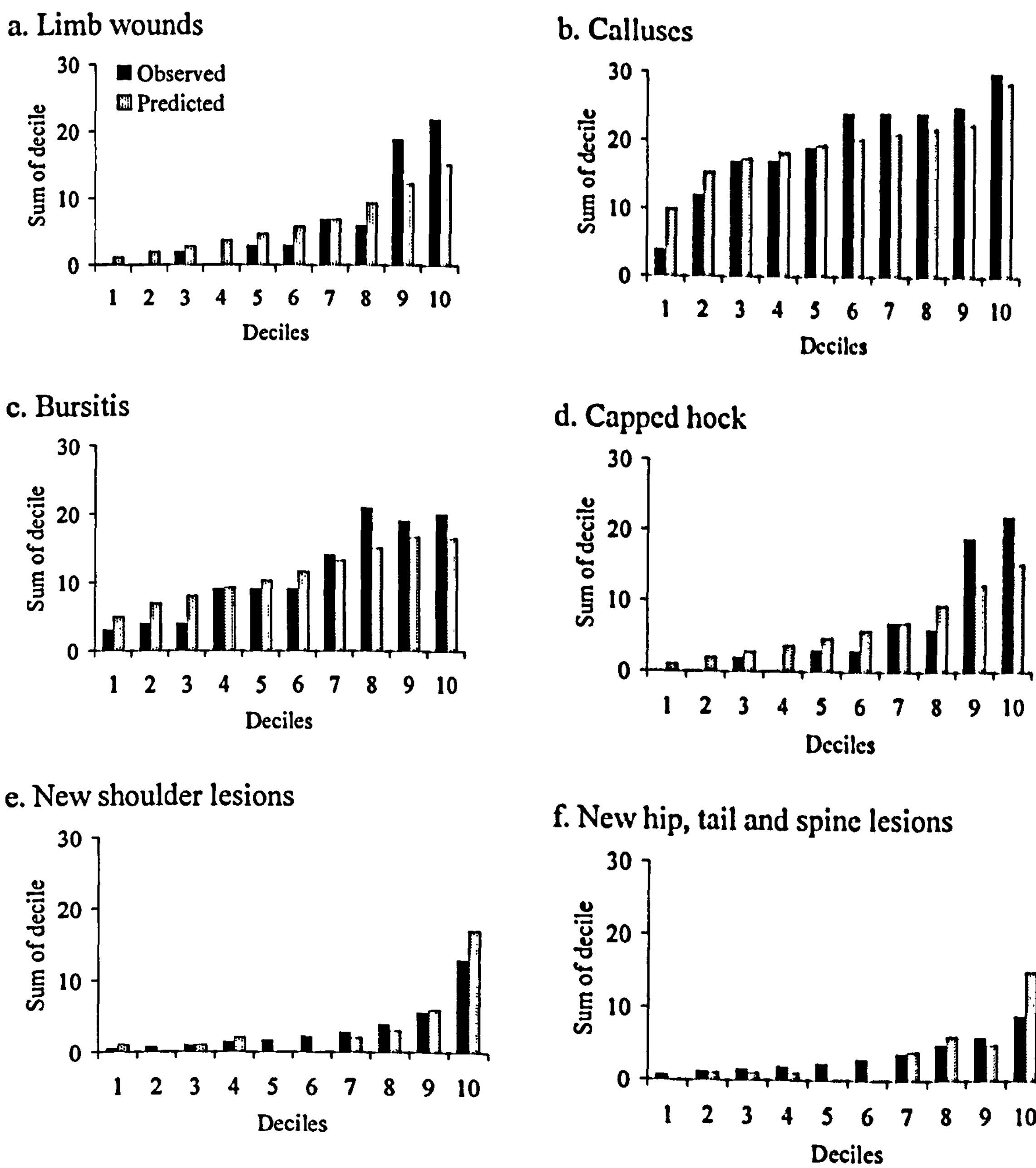
5.3.4.3 New hip, spine and tail lesions

None of the 41 outdoor housed sows in the risk factor analysis had a new lesion on the hip, spine or tail. In indoor housed lactating sows the risk of new lesions on the hips, spine or tail was lower in sows with 10-20cm or >20cm between the sow's tail and the back of the crate compared with sows in crates with <10cm between the sow's tail and the back of the crate. (Table 5.5).

5.3.5 Model fit and observer differences

The Hosmer-Lemeshow goodness-of-fit statistic indicated that the difference between the observed and predicted values in the models was generally small (Table 5.5). Graphs of predicted verses observed values indicated that there was a trend for the models to under predict the prevalence of limb lesions but over predict the prevalence of body lesions in the higher deciles (Figure 5.1). Controlling for the observer did not alter the interpretation of the fixed effects in any of the models.

Figure 5.1: Graphs a-f of observed verses predicted values from logistic binomial regression models of limb and body lesions in lactating sow



5.3.6 Associations between limb and body lesions and slat material

There were no significant associations between slat material (metal or plastic) and the prevalence of any limb or body lesions in indoor housed lactating sows (data not shown).

5.3.7 Correlations between limb and body lesions

Bursitis was positively correlated with calluses and wounds on the limbs. Calluses were positively correlated with wounds on the limbs and capped hocks. New shoulder lesions were positively correlated with calluses on the limbs. New lesions on the hip, spine or tail were positively correlated with bursitis and calluses on the limbs. (Table 5.7).

Table 5.7: Correlations between limb and body lesions in indoor and outdoor lactating sows

		Shoulder lesions		Hip, spine or tail lesions		Bursitis	Calluses	Wounds on limbs
		New	Scars	New	Scars			
Shoulder lesions	New	1.00						
	Scars	-0.03	1.00					
Hip spine tail lesions	New	0.05	-0.03	1.00				
	Scars	-0.03	-0.02	-0.02	1.00			
Bursitis		0.01	-0.01	0.16*	0.08	1.00		
Calluses		0.18*	0.09	0.12*	-0.06	0.12*	1.00	
Wounds on limbs		0.08	0.06	0.09	-0.03	0.14*	0.17*	1.00
Capped hock		0.09	0.04	0.02	0.09	0.02	0.18*	0.02

* significantly correlated at $p<0.05$

5.3.8 Correlations between parity, body condition and crate space

As the parity of the lactating sow increased the body condition increased ($r = 0.20$, $df = 219$, $p < 0.05$) and the space in the crate decreased (between the sow's back and the top of the crate; $r = -0.37$, $df = 219$, $p < 0.05$, between the sow's tail and the back of the crate; $r = -0.28$, $df = 219$, $p < 0.05$). Sows that had less space within the crate between the sow's tail and the back of the crate were less likely to respond to human presence ($r = 0.13$, $df = 278$, $p<0.05$).

5.3.9 Population attributable fractions

Assuming a causal relationship between floor type and limb and body lesions, the prevalence of injuries in the affected population would be reduced by between 32% and 100% (depending on the type of lesion) if sows currently housed indoors during lactation were housed outdoors. This is also based on the assumption that sows would also be housed outdoors during pregnancy, as occurred in the outdoor housed lactating sows in this sample. For all types of limb and body lesions the largest proportion of lesions were attributable to part slatted floors with or without bedding (Table 5.8)

Table 5.8: Population attributable fractions of limb and body lesions in indoor and outdoor housed lactating sows

	Limb lesions n = 279				Body lesions n = 288	
	Wound	Callus	Bursa	Capped hock	Shoulder	Hip, spine and tail
Outdoor						
Solid concrete with bedding	9.8	7.3	8.8	4.0	5.8	5.5
Partly slatted with bedding	7.8	11.8	17.6	8.8	14.8	14.9
Partly slatted without bedding	62.7	9.3	34.8	25.8	37.1	29.2
Fully slatted	19.6	9.3	7.8	6.3	14.2	11.7
Total reduction	100	56.3	69.0	44.9	71.9	61.3

5.4 Discussion

This is the first study to provide a measure of the prevalence of limb and body lesions in lactating sows from a cross-section of English pig farms. The previous studies have been conducted on experimental units or small numbers of farms, in other countries or used different samples, e.g., culled sows or including pregnant sows (Edwards and Lightfoot, 1986; von Berner *et al.*, 1990; Davies *et al.*, 1996; Leeb *et al.*, 2001; Zurbrigg, 2006).

The prevalence of limb and body lesions in indoor housed lactating sows was high, while the prevalence in sows housed outdoors was significantly lower. The use of farrowing crates, commonly with slatted floors, makes the contrast between indoor and outdoor housing particularly notable during lactation. Compared with pregnant sows, lactating sows had a higher prevalence of calluses, bursitis and capped hock and had wounds on the limbs and bodies. This might be an indication that the farrowing pen environment is more challenging for sows than the pregnant sow housing.

The prevalence of wounds on the limbs and body was highest in the first week of lactation, we know from observations of pregnant sows on these farms (Chapter 4) that it is unlikely that the sows entered the farrowing crates with these lesions. It is probable that these lesions developed when the sows first entered the crate prior to farrowing and in the days immediately following (no sows were examined until 3 days post partum), because sows were unaccustomed to having their movement restricted (De Koning, 1984; Boyle *et al.*, 2002) and because sows spent a large amount of time lying recumbent (Davies *et al.*, 1996; 1997)

Sows that had less space, and so were most closely restrained within the crate, had an increased risk of body lesions and calluses on the limbs, possibly because they were more likely to injure themselves against the crate. Also, as one might assume for calluses, because it was harder for them to change position and move to standing (Curtis *et al.*, 1989) and therefore they spent more time kneeling or lying with their limbs folded underneath. Older sows, which are larger, have less space in the crate and are therefore at an increased risk of developing body lesions and calluses.

As in previous studies (Edwards and Lightfoot, 1986; Davies *et al.*, 1996; Leeb *et al.*, 2001; Bonde *et al.*, 2004), there was an overall trend for the risk of calluses, capped hock, limb wounds and body lesions to increase as the proportion of slatted floor in the farrowing crate increased and the quantity of bedding decreased. The risk of bursitis did not differ with floor type, however the prevalence of bursitis increased the longer the sow had been in the farrowing crate, suggesting that all floors were sufficiently hard to cause bursae to develop.

In addition to the effect of floor type, there was an increased risk of bursitis, capped hock and shoulder lesions in sows that were less willing to rise to their feet. This might occur because these sows spent more time lying down. Alternatively, floors that increase the risk of these lesions may also be floors where rising is difficult, e.g. slippery, or, once sows develop these lesions, they may experience sufficient discomfort to discourage them from rising to their feet. Lack of responsiveness itself could be an indication that the sow is shutting out environmental stimuli which can be a sign that the animal is having difficulty coping with its environment (Broom, 1991).

It is unclear why a film of dry slurry on the floor reduced the risk of wounds on the limbs and capped hock. But a similar pattern was reported for calluses in gilts and pregnant sows (Chapter 4). It is possible that the coating of dry dung made the floor less slippery, abrasive or hard. Wet and rough floors probably increased the risk of shoulder sores, as reported in previous studies (Davies *et al.*, 1996; 1997; Bonde *et al.*, 2003; Zurbrigg, 2006) because the skin becomes softer and was then abraded by the rough floor.

There might be a reduced risk of bursitis with increasing body condition because subcutaneous fat protects against bursitis (Smith, 1993) or makes bursitis harder to detect. It is unclear why this effect was not evident in pregnant sows, but it is possible that few new bursae develop during this stage. Conversely, increased body condition was associated with a trend for an increased prevalence of capped hock, as reported in pregnant sows (Chapter 4). This might have occurred because heavier or older sows are at increased risk of capped hock or there might have been misclassification of sows with fatty hocks.

As reported in several previous studies (Davies *et al.*, 1996; Bonde *et al.*, 2004; Zurbrigg, 2006; Karlen *et al.*, 2007; Knauer *et al.*, 2007), there was a trend for the risk of wounds on the limbs and body to increase in sows with lower body condition, where there is less subcutaneous fat over the bony protuberances. It might not have reached significance in the current study because the majority of sows in this sample had good body condition (Chapter 2, section 2.15.2).

The sample size of lactating sows examined in the current study was relatively small, therefore the power to detect significant associations between exposures and disease was reduced. Despite this, many useful hypotheses were generated from the data collected. In lactating sows housed indoors, associations between disease and the environment were easy to detect because of the sows close confinement. That is, if the floor within the crate was wet, rough, or damaged there is no doubt that the sow was exposed to these factors, while in loose housed sows (e.g., during pregnancy) the sow might be able to avoid lying in these areas if they found them to be uncomfortable. Hence, what is one of the problems of farrowing crates for the welfare of the sow, that is, the restricted freedom to take action to cope with the environment, has the effect of simplifying the science. Additionally, information about the sow, such as parity or how long the sow had been in the pen were readily available and it was easy to make close observations on the sow because she was confined in the farrowing crate.

5.4.1 Conclusions

Lactating sows housed outdoors had the lowest prevalence of limb and body lesions. Indoors there was a general trend for an increased risk of limb lesions in lactating sows housed on slatted floors compared with those housed on solid concrete floors with bedding. Sows that had less space within the farrowing crate had an increased risk of wounds on the body and calluses on the limbs.

Chapter 6

Foot and limb lesions in preweaning piglets

6.1 Introduction

Farrowing pen floors made of concrete and metal or plastic slats are much harder than the soil on which piglets' feet and limbs have evolved. Preweaning piglets housed on such floors often develop hairless patches or abrasions on their limbs (Penny *et al.*, 1971; Svendsen *et al.*, 1979; Furness *et al.*, 1986; Mouttotou and Green, 1999; Mouttotou *et al.*, 1999a). Skin abrasions occur most frequently on carpal joint of the forelimbs and at a decreasing prevalence on the carpophalangeal joint and the hock (Penny *et al.*, 1971; Svendsen *et al.*, 1979; Furness *et al.*, 1986). Injuries to the feet include sole bruising, which presents as dark red pigmentation and sole erosion where the sole surface is abraded (Smith and Mitchell, 1977; Mouttotou and Green, 1999; Mouttotou *et al.*, 1999a; Zoric *et al.*, 2004). Localised infections in the feet and limbs, resulting from invasion by opportunistic pathogens, present as swollen joints and claws (Penny *et al.*, 1971; Gardner *et al.*, 1990; Zoric *et al.*, 2004).

From studies on single farms, the prevalence of skin abrasion, sole bruising, sole erosion and swollen joints or claws have been estimated at 80 - 89% (Penny *et al.*, 1971; Zoric *et al.*, 2004), 87 -100% (Smith and Mitchell, 1977; Zoric *et al.*, 2004), 28% (Smith and Mitchell, 1977) and 6 – 8% (Smith and Mitchell, 1977; Gardner *et al.*, 1990) respectively. In the only cross sectional study of the prevalence of foot and limb lesions in preweaning piglets published to date, Mouttotou *et al.* (1999a) examined 264 piglets from 13 farms in Britain and reported that 36% of piglets had skin abrasion and 50% had sole bruising, the prevalence of other lesions was not recorded. Skin abrasion and sole bruising occur soon after birth; the prevalence is high in the first week of life and then decreases as the lesions resolve (Svendsen *et al.*, 1979; Phillips *et al.*, 1995; Mouttotou *et al.*, 1999a; Mouttotou and Green, 1999; Zoric *et al.*, 2004).

Research to date indicates that skin abrasion is more likely to occur on floors that are abrasive, such as concrete floors without a deep protective covering of bedding (Svendsen *et al.*, 1979; Furniss *et al.*, 1986; Christison *et al.*, 1987; Mouttotou *et al.*, 1999a). Small quantities of bedding provide little protection against skin abrasion, probably because the bedding is too easily moved aside to expose the floor surface as the piglets scrabble to feed (Smith and Mitchell, 1977; Svendsen *et al.*, 1979; Furniss *et al.*, 1986). Bedding may even exacerbate skin abrasions because shards may be pushed through the epidermis (Mouttotou *et al.*, 1999a).

Slatted floors have been reported to be associated with an increased risk of sole bruising compared with solid floors, probably due to the lack of bedding and the reduced weight bearing surface area of the floor (Mouttotou *et al.*, 1999a). Sparse bedding reduced the prevalence of sole bruising on the feet compared with unbedded pens and the prevalence of sole bruising reduced further when deep bedding was provided (Mouttotou *et al.*, 1999a).

While bruising and erosion or abrasion appear to have purely mechanical causes, the risk of infection is multifactorial and determined by contact with an infectious pathogen, an entry site in the epidermis, the piglets' immune response and treatments administered by the farmer. Lesions on the feet and limbs may provide entry sites for infection. But little is currently known about the pathology of foot and limb lesions and whether they are commonly accompanied by infection. In a study of the risks associated with foot abscesses Gardner *et al.* (1990) reported that sow illness and large litter size increased the risk of infection, while prophylactic antibiotic injection reduced the risk. It is possible that the type of floor and the use of bedding might influence contact between piglets and pathogens (Rantzer and Svendsen, 2001) which might affect the prevalence of infections in the feet and limbs. Although, Christison *et al.* (1987) reported no difference in the prevalence of joint infections by floor type in piglets on an experimental unit in Canada.

In summary, previous literature has indicated that the risk of injuries to piglets are minimised by a clean, soft, non abrasive environment. However, the environmental needs of piglets cannot be separated from the requirements of the lactating sow. The sow's needs include a comfortable surface for lying, space and a non slip surface for rising and standing and separation from excreta (Chapter 5).

In this chapter, the prevalence, population attributable fractions and associations with the environment for foot and limb lesions in preweaning piglets is presented. In addition, the pathology associated with examples of these lesions is reported.

6.2 Materials and Methods

6.2.1 Data collected

On each farm four litters of piglets were randomly selected, one each aged 3 – 7, 8 – 14, 15 – 21 and 22 – 28 days of age. Observations were made on all piglets in each litter. All four limbs and feet were examined for lesions (Chapter 2, Table 2.3 and Table 2.4). Data were recorded on the floor type, floor condition, bedding, and the number of piglets in the litter (Chapter 2, Table 2.7). Risks associated with the prevalence of limb and foot lesions were investigated with binomial models where the outcome was the proportion of piglets affected (score 1-3) in each litter (Section 2, 2.13). Risks associated with hairless patches were not investigated because hairless patches and healed skin abrasions could not be differentiated.

6.2.2 Sample of pigs

A total of 3,206 piglets from 339 litters were examined; 289 litters were housed indoors and 50 outdoors. Of this total, prevalence was calculated in 2,843 piglets from the ABP English farms for which there was complete foot and limb data.

6.2.3 Pathology

Two samples each of sole bruising, sole erosion, skin abrasion and swollen joints or claws of each score 0-3 were selected from two convenience selected farms. Each lesion was described by the pathologist (P. Ossent) using gross and histological examination and the severity of the internal lesion was compared with the clinical presentation (Chapter 2, section 2.12).

6.3 Results

6.3.1 Prevalence of foot and limb lesions in 2,843 preweaning piglets

The prevalence of sole bruising and sole erosion on the piglets' feet was 48.8% and 15.3% respectively. The prevalence of skin abrasions and hairless patches on the limbs was 43.0% and 61.3% respectively. There were 4.7% of piglets with swollen joints or claws. The prevalence and severity of all lesions was lower in piglets housed outdoors compared with piglets housed indoors (Table 6.1). None of the outdoor housed piglets had swollen joints or claws and the modal maximum lesion score for all other lesions was one. In indoor housed piglets the modal maximum lesions score for sole bruising and erosion was one and for hairless patches, skin abrasions and swellings it was two (Table 6.1).

Table 6.1: Number and percent of 2843 indoor and outdoor housed piglets with foot and limb lesions score 0 – 3

		Score 0		Score 1		Score 2		Score 3	
Lesion		n	%	n	%	n	%	n	%
Sole bruising	Indoor	1042	43.0	807	33.3	452	18.6	123	5.1
	Outdoor	415	99.0	3	0.7	1	0.2	0	0.0
Sole erosion	Indoor	2010	82.9	281	11.6	104	4.3	29	1.2
	Outdoor	398	95.0	14	3.3	6	1.4	1	0.2
Skin abrasion	Indoor	1218	50.2	424	17.5	523	21.6	259	10.7
	Outdoor	400	95.5	19	4.5	0	0.0	0	0.0
Hairless patch	Indoor	769	31.7	502	20.7	707	29.2	446	769
	Outdoor	330	78.8	53	12.6	33	7.9	3	330
Swollen joint /claw	Indoor	2291	94.5	43	1.8	56	2.3	34	1.4
	Outdoor	419	100.0	0	0.0	0	0.0	0	0.0

The prevalence of lesions varied by limb and foot (Table 6.2). Skin abrasions and hairless patches occurred at the highest prevalence on the fore limb carpal joints and at a lower prevalence on the carpophalangeal joints and on the hind limbs. There was a slightly higher prevalence of sole bruising on the fore feet compared with the hind and conversely a higher prevalence of sole erosion on the hind feet compared with the fore. Lesions were equally prevalent on the right and left sides (Table 6.2). The prevalence of some foot and limb lesions in preweaning piglets varied by age, floor type and floor condition (Table 6.3).

Table 6.2: Number and percent of 2,843 piglets with foot and limb lesions by location

		Sole bruising		Sole erosion		Skin abrasion		Hairless patch		Swollen joint /claw	
Limb	Location	n	%	n	%	n	%	n	%	n	%
Fore right	Carpal					1032	36.3	1308	46.0	14	0.5
	Carpoph.*					532	18.7	1077	37.9	17	0.6
	Foot	1146	40.3	489	17.2					11	0.4
Fore left	Carpal					873	30.7	1305	45.9	26	0.9
	Carpoph.					517	18.2	1109	39.0	26	0.9
	Foot	1140	40.1	478	16.8					14	0.5
Hind right	Tarsal					287	10.1	574	20.2	28	1.0
	Carpoph.									11	0.4
	Foot	1060	37.3	589	20.7					6	0.2
Hind left	Tarsal					279	9.8	583	20.5	9	0.3
	Carpoph.									14	0.5
	Foot	1035	36.4	577	20.3					14	0.5

* carpophalangeal joint

Table 6.3: Number and percent of preweaning piglets with foot and limb lesions by age, floor type and floor condition

	Sole bruising		Sole Erosion		Skin abrasion		Swollen joint / claw		Total
	n	%	n	%	n	%	n	%	n
Age									
1-week	551	75.8	97	13.3	415	57.1	28	3.9	727
2-week	465	55.4	130	15.5	431	51.4	41	4.9	839
3-week	240	36.9	117	18.0	212	32.6	32	4.9	651
4-week	130	20.8	91	14.5	167	26.7	32	5.1	626
Floor / bedding									
Solid concrete with bedding	124	37.6	41	12.4	167	50.6	13	3.9	330
Partly slatted with bedding	320	58.3	72	13.1	250	45.5	24	4.4	549
Partly slatted with bedding in some areas	351	72.1	146	30.0	293	60.2	40	8.2	487
Part slatted no bedding	546	56.4	215	22.2	432	44.6	53	5.5	969
Fully slatted	253	61.6	49	11.9	209	50.9	34	8.3	411
Outdoor	4	1.0	21	5.0	19	4.5	0	0.0	419
Worn rough sow lying area									
No	1084	56.3	320	16.6	918	47.7	109	5.7	1925
Yes	270	65.5	86	20.9	257	62.4	27	6.6	412
Worn rough sow dunging area									
No	1278	56.5	381	16.8	1117	49.4	120	5.3	2262
Yes	79	63.7	32	25.8	71	57.3	17	13.7	124
Wet floor in the lying area									
No	1273	58.3	430	19.7	1068	48.9	130	6.0	2184
Yes	303	62.5	84	17.3	261	53.8	32	6.6	485

6.3.2 Risk factors associated with foot and limb lesions in preweaning piglets

6.3.2.1 Sole erosion

There was a reduced risk of sole erosion associated with piglets housed outdoors compared with piglets housed indoors (OR 0.1, CI 0.1, 0.5). Indoors, there was an increased risk of sole erosion in piglets on partly slatted floors with bedding in some areas or no bedding compared with solid concrete floors with bedding throughout the pen. There was no significant difference in the prevalence of sole erosion in piglets housed in partly slatted floors with bedding or fully slatted floors, compared with solid concrete floors with bedding. A wet floor in the sow lying area was associated with a reduced risk of sole erosion compared with a dry floor. There was no significant association between the prevalence of sole erosion and the age of the piglet in weeks (Table 6.4).

6.3.2.2 Sole bruising

There was a reduced risk of sole bruising associated with outdoor housed piglets compared with indoor housed (OR 0.005, CI 0.002, 0.01). In indoor housed piglets, the risk of sole bruising decreased with each increasing week of age. There was an increased risk of sole bruising associated with partly slatted floors with and without bedding and fully slatted floors, compared with solid concrete floors with bedding (Table 6.4).

Table 6.4: Two level logistic binomial models of the risks associated with foot and limb lesions in preweaning piglets

All pens	Sole bruise 286 pens		Sole erosion 278 pens		Skin abrasion 278 pens		Swollen joint / claw 284 pens		Skin abrasion <1-wk 71 pens	
Intercept coefficient		2.2		-2.0		1.5		-3.8		1.2
	OR	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Age	0.3	0.3, 0.4	1.0	0.9, 1.2	0.6	0.5, 0.7	1.1	0.9, 1.3		
Floor/Bedding										
Solid concrete with bedding										
Partly slatted with bedding	2.2	1.1, 4.6	1.3	0.5, 3.0	0.6	0.3, 1.1	1.4	0.6, 3.5	0.6	0.2, 2.0
Partly slatted with bedding in some areas	4.2	2.0, 9.0	2.9	1.2, 7.1	1.0	0.6, 1.8	2.5	1.1, 6.1	0.8	0.2, 2.8
Partly slatted no bedding	2.6	1.3, 5.0	2.4	1.1, 5.5	0.7	0.4, 1.1	1.7	0.7, 3.9	0.4	0.1, 1.2
Fully slatted	3.0	1.4, 6.5	1.3	0.5, 3.3	0.9	0.5, 1.7	3.0	1.2, 7.4	0.3	0.0, 0.9
Wet sow lying area										
No										
Yes			0.5	0.3, 0.9						
Worn sow lying area										
No										
Yes					1.6	1.1, 2.4			3.0	1.5, 6.0
Worn sow dunging area										
No										
Yes							2.8	1.3, 6.0		
Random effects	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**
Farms	0.5	0.2	1.1	0.3	0.2	0.1	0.3	0.2	0.7	0.2
Pens	1.0	0.2	0.8	0.2	0.8	0.1	0.6	0.3		
Hosmer-Lemeshow goodness-of-fit	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**
	0.5	0.78	6.2	0.10	3.2	0.52	3.8	0.20	0.4	0.98

6.3.2.3 *Skin abrasion*

6.3.2.3.1 *Piglets 1 – 4 weeks of age*

There was a reduced risk of skin abrasion in piglets housed outdoors compared with piglets housed indoors (OR 0.04, CI 0.02, 0.07). In indoor housed piglets the risk of skin abrasion decreased with each week of age from 1-4 weeks. There was no significant difference in the prevalence of skin abrasion in piglets aged 1-4 weeks of age housed indoors on different floor types (Table 6.4).

6.3.2.3.2 *Piglets 1 week of age or less*

In piglets 1-week of age or less, there was a reduced risk of skin abrasions in piglets housed on fully slatted floors, compared with piglets housed on solid concrete floors with bedding. There was an increased risk of skin abrasion in piglets 1-week old or less in pens with a worn rough floor surface in the sow lying area compared with a even floor surface (Table 6.4).

6.3.2.4 *Swollen joints or claws*

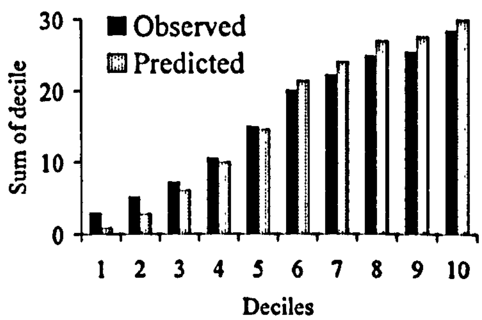
There was increased risk of swollen joints or claws in pigs on partly slatted floors with some bedding and fully slatted floors, compared with solid concrete floors with bedding. Partly slatted floors without bedding were not significantly different from the reference floor type. There was an increased risk of swollen joints and claws when the sow's dunging area was rough and worn compared with a smooth floor in the sow dunging area (Table 6.4). On partly slatted floors with bedding, there was a trend for a reduced risk of joint swelling associated with plastic slats compared with metal (OR 0.4, CI 0.2, 1.1).

6.3.2.5 Model fit and observer differences

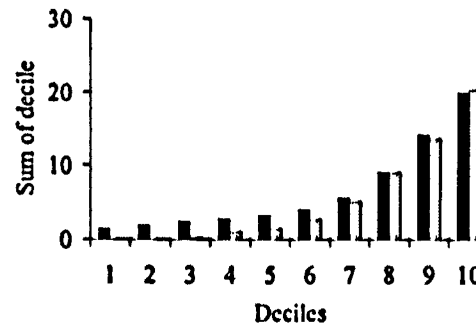
For all preweaning piglet foot and limb models the Hosmer-Lemeshow goodness-of-fit statistic and the graphs indicated that the difference between the observed and predicted values was small (Table 6.4 and Figure 6.1). Controlling for the observer did not alter the interpretation of the fixed effects in any of the models.

Figure 6.1: Graphs a – e observed verses predicted values from logistic binomial regression models for foot and limb lesions in preweaning piglets

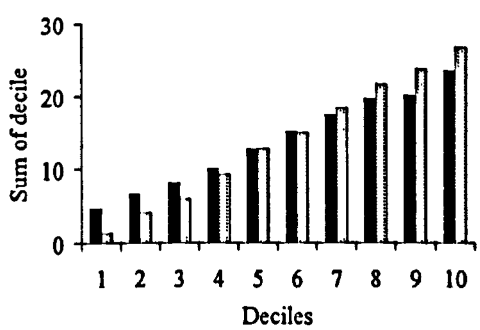
a. Sole bruising



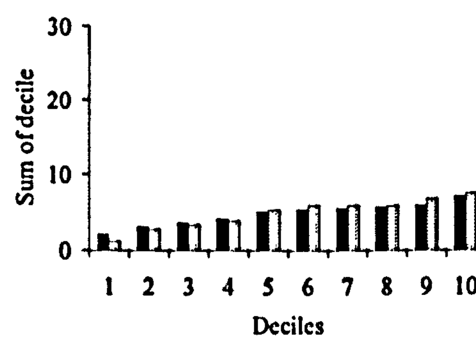
b. Sole erosion



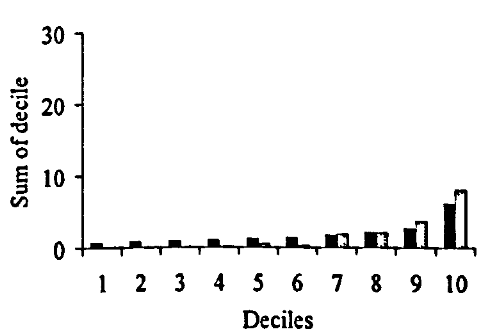
c. Skin abrasion



d. Skin abrasion in piglets aged ≤1wk



e. Swollen joints or claws



6.3.3 Associations between foot and limb lesions in indoor and outdoor housed piglets

Correlated variables were statistically significant at a low level due to the large sample size (Table 6.5). The strongest correlations were a positive correlation between sole bruising and skin abrasion, a negative correlation between skin abrasion and hairless patches and a positive correlation between sole bruising and sole erosion.

Table 6.5: Correlations between limb and foot lesions in indoor and outdoor housed piglets

	Sole bruising	Sole erosion	Skin abrasion	Hairless patch	Swollen joint /claw
Sole bruising	1.00				
Sole erosion	0.16*	1.00			
Skin abrasion	0.30*	0.12*	1.00		
Hairless patch	-0.17*	0.13*	-0.20*	1.00	
Swollen joint /claw	0.05*	0.06*	0.12*	0.07*	1.00

* significantly correlated at $p < 0.05$

6.3.4 Pathology

A total of 24 samples of foot and limb lesions were taken for pathological examination from 17 piglets. The median age of the piglets was 7 days (IQR 6, 9). The thickness of the horn on the heel was measured to be between 1-2mm. The skin abrasions were mainly without secondary infection (Figure 6.2) and were considered by the pathologist (P. Ossent) as likely to be painful as they developed but unlikely to be associated with discomfort at the time of euthanasia, once healing had begun. The pathology associated with the foot lesions was more severe. Pathological alterations included necrosis in the horn layers with inflammation of the heel and formation of a flap of horn (B) (Figure 6.3). Ulceration of the heel horn with focal pododermatitis (inflammation of the skin which lies under the hoof and secretes the horny structure) also occurred (Figure 6.4). In the most severe examples large abscesses were present, as illustrated in Figure 6.5 between the coronary band and the wall horn (D). In this case imflammatory infiltrates (white blood cells which leave the blood and infiltrate the inflamed connective tissue) extended all the way down the wall to the tip of the toe (E) and there was osteomyelitis (inflammation of bone) of the third phalanx with purulent inflammation and extensive necrosis and dissolution of the bone (F).

Figure 6.2: Histological section of a skin abrasion on the fore limb of a preweaning piglet with inflamation and ulceration of the skin (A)

Figure 6.3: Histological section of a piglet's claw with inflammation of the heel and a flap of loose horn tissue (B)

Figure 6.4: Histological section of a piglets claw with focal pododermatitis (C) of the heel

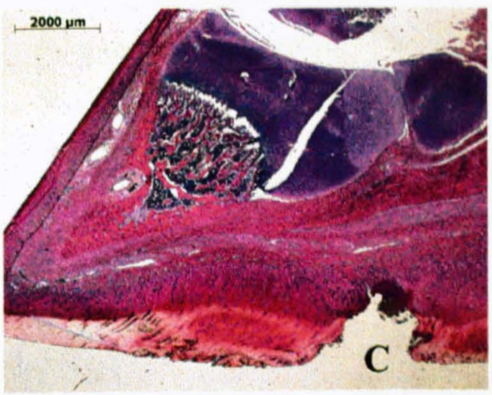
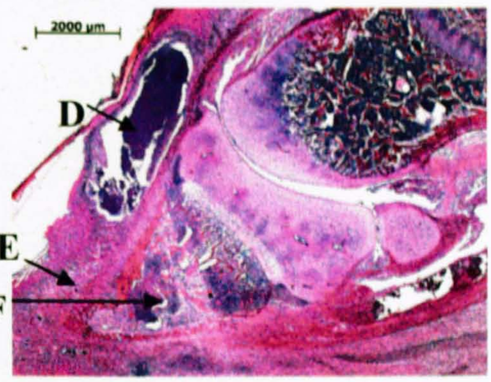


Figure 6.5: Histological section of a piglet's claw with an abscesses (D) imflammatory infiltrates (E) and osteomyelitis (F)



There was poor correlation between the external indication of infection i.e., swelling and evidence of inflammation and infection identified in pathological examination. However, the samples selected clinically as examples of unaffected feet and limbs were confirmed post-mortem as normal.

6.3.5 Population attributable fractions

Assuming a causal relationship between floor type and foot and limb lesions, the prevalence of lesions in the affected population would be reduced by between 68% and 100%, if piglets currently housed indoors were housed outdoors. For all types of foot and limb injury the largest proportion of lesions was attributable to partly slatted pens without bedding (Table 6.6).

Table 6.6: Population attributable fractions for foot and limb lesions in 2878 preweaning piglets

	Sole bruising	Sole erosion	Skin abrasion	Swollen joint /claw
Outdoors				
Solid concrete with bedding	8.7	5.5	12.3	9.4
Part slatted with bedding	19.5	8.5	15.9	9.2
Part slatted some bedding	19.6	19.1	18.0	23.6
Part Slatted no bedding	35.2	33.8	29.9	35.4
Fully slatted	14.3	1.4	13.0	21.4
Total reduction	97.3	68.3	89.1	100

6.4 Discussion

The current study is, to the author's knowledge, to date the largest cross-sectional study of the prevalence of foot and limb lesions in preweaning piglets. It is the first to examine piglets housed outdoors. As reported in post weaning pigs and sows (Chapters 3, 4 and 5); soil with a deep covering of straw, which provides a soft, non abrasive surface, was associated with the lowest prevalence of foot and limb lesions in preweaning piglets. None of the indoor floor types currently used in commercial pig farms in England can be considered ideal for preweaning piglets; the risk was between 5-200 times higher (depending on the type of lesion) in piglets housed indoors compared with piglets housed outdoors. The prevalence of skin abrasion and sole bruising in indoor housed piglets were slightly higher than reported in the previous cross sectional English study (Mouttotou *et al.*, 1999a).

The type of injury that occurred was associated with the floor construction and condition. Slatted floors might have increased the risk of sole bruising because of the lack of bedding and the increased pressure on the weight bearing areas of the foot. The voids might also cause a particular problem when the piglets' claws were small enough to enter the void and pressure from the edge of the slat might bruise the sole.

Areas of solid concrete floor without bedding (in part slatted pens) were probably associated with an increased risk of sole erosion because the concrete was rough and abraded the horn. The thickness of the horn was 1 – 2 mm in the sample of young piglets examined post-mortem in the current study and is therefore likely to be easily damaged. The reduced risk of sole erosion associated with a wet floor surface in the area where the piglets suckled the sow may have occurred because piglets spent less time in this wet area and more time in the creep, where the floor was possibly less abrasive and more likely to have bedding (Mouttotou *et al.*, 1999a). Alternatively, the wetness of the floor may be acting as a proxy for a floor construction variable that was not measured. There was a trend for a higher prevalence and larger sole erosion on the hind feet. Smith and Mitchell (1977) proposed this might occur because the piglets push forward with their hind limbs when standing to suckle from the sow.

It was not possible to differentiate between a hairless patch on a piglet's limb which occurred without damage to the skin and a healed skin abrasion where the hair had not yet re-grown. This meant that piglets aged 2 – 4 weeks might have been misclassified as affected with a hairless patch when in fact the lesion was a healed skin abrasion. This might explain why there was no association between skin abrasion and floor type when piglets of all ages were included in the model. The reduced risk of skin abrasion in piglets 1-week old or less housed on part or fully slatted floors without bedding might have occurred because these floors were made from metal or plastic slats, which was less abrasive than concrete. In the current study, the risk of skin abrasion also increased when the floor was worn and rough and with small amounts of bedding, as reported in previous studies (Furniss *et al.*, 1986; Svendsen *et al.*, 1979; Mouttotou *et al.*, 1999a). Also as previously reported (Penny *et al.*, 1971; Svendsen *et al.*, 1979; Furness *et al.*, 1986) and similar to calluses in older pigs (Chapters 3, 4, 5 and 6), hairless patches and skin abrasions were more prevalent and larger on the fore limbs. The highest prevalence occurred on the carpal joint, which takes the majority of the weight of the piglet when it kneels to suckle.

The fact that slatted floors, that are supposedly cleaner, were associated with an increased risk of swollen joints and claws was a surprising result. It may be an indication that slatted floors did not reduce contact with pathogens, or did not do so sufficiently to reduce prevalence of infections compared with solid concrete floors with bedding. Further research is required to understand whether floor type is causal or whether a correlated herd or management factor explains the association. In the current study, the farmer's treatment of affected pigs was unknown and this may have affected the outcome. In previous studies large litters have been reported to be associated with an increased risk of swollen joints (Gardner *et al.*, 1990) but litter size, as observed at the time of the visits, was not associated with the prevalence of swollen joints and claws in the current study.

The increased risk of swollen joints and claws associated with a worn floor surface and a trend for an increased risk with metal slats compared with plastic, might have occurred because these floors are harder to keep clean, or because these features occurred in older pens which may be associated with generally lower standards of housing and management.

It is unclear whether the zero prevalence of foot and limb infections in piglets housed outdoors occurred because there were less entry sites for infection e.g. tail and tooth clipping and fewer foot and limb injuries, or because they had less contact with pathogens. The association between injuries that might act as entry sites for infection (skin abrasions or sole erosions) and swollen joints or claws was weak, although statistically significant due to the large sample size. It might be that with a cross-sectional design it is difficult to identify the association because the lesions had resolved by the time the swollen joints or claws developed. Additionally the results from the pathology study indicated that the prevalence of claws identified as swollen might be an underestimation of the prevalence of infection, because infection was present in claws that were not visibly swollen.

It is also possible that not all entry sites for infection were recorded in the cross-sectional dataset. Feet examined post-mortem had injuries at the coronary band. The prevalence of these lesions or the associated risks in the study sample is not known. But it appeared likely they were caused by the edge of the slat when the hoof enters the void, possibly accompanied by bruising on the sole of the foot where it contacts with the other slat edge. A longitudinal study following the development of lesions over time would be useful to investigate whether lesions where the epidermis was broken, including these lesions at the coronet band, were subsequently associated with an increased prevalence of foot and limb infections.

Sole bruising and skin abrasion were positively associated within piglets as reported in previous studies (Mouttotou *et al.*, 1999a) and sole bruising accompanied sole erosion. Hairless patches were negatively associated with skin abrasions because, as previously discussed, many hairless patches arise from healed skin abrasions. The high prevalence of sole bruising and skin abrasion in the first week of life which then decreased with age has been reported in several previous studies (Svendsen *et al.*, 1979; Phillips *et al.*, 1995; Mouttotou and Green, 1999; Mouttotou *et al.*, 1999a; Zoric *et al.*, 2004). It is likely that the feet and limbs of newborn piglets are particularly soft and vulnerable. But it is unknown whether piglets protected against injury at this stage would simply develop this damage at a later age.

One of the strengths of the current study is that the impact of the floor on the sow and piglets can be compared (Table 6.7).

Table 6.7: Summary of associations between limb and foot lesions and farrowing pen floor type in lactating sows and piglets

	Lactating sows					Piglets		
	Callus	Wound on limb	Bursitis	Capped hock	Body lesion	Skin abrasion	Sole bruise	Sole erosion
Solid concrete floors with bedding								
Part slatted floors with bedding	▲		-		-	-	-	-
Part slatted floors with* bedding in some areas	NA	NA	NA	NA	NA	-	▲	▲
Part slatted floors with no bedding	▲	-	-	▲	-	▼	▲	▲
Fully slatted floors	▲	▲	-	▲	-	▼	▲	-
Outdoor housing	▼	▼	▼	▼	▼	▼	▼	▼

▲= an increase in risk compared with solid concrete floors with bedding
▼= a decrease in risk compared with solid concrete floors with bedding
- = no significant difference compared with solid concrete floors with bedding

*this category was not applicable to sows restrained within farrowing crates

For lactating sows, as for piglets, outdoor housing was associated with a significantly lower prevalence of limb lesions compared with indoor housing. Although, the prevalence of limb lesions in outdoor housed lactating sows was considerably higher than in outdoor housed piglets. This may be an indication that these lesions develop over time even in the softer outdoor environment, or that these sows have been housed indoors previously. One of the advantages of sampling piglets is that they do not commonly move housing during the preweaning period so it is easier to be sure that the damage observed is caused by the floor they are currently housed on.

In the current study potential conflict between the flooring needs of sows and piglets, as previously suggested by Furniss *et al.* (1986), was illustrated. Slatted floors increased the prevalence of wounds on the limbs of lactating sows (Chapter 5), probably because they increase the pressure on weight bearing areas while the sows is lying, yet slatted floors were associated with a lower prevalence of skin abrasions on the piglets limbs in the first week. However, it is worth noting that if it were practical to provide sows and piglets indoors with solid floors with sufficiently deep bedding to protect them from the surface of the concrete, such floors might be associated with a low prevalence of all lesions, as observed in outdoor housed pigs.

6.4.1 Conclusions

Preweaning piglets housed outdoors in huts with deep straw bedding had the lowest prevalence of all foot and limb lesions. In piglets housed indoors, no one floor type can be considered ideal; slatted floors were associated with an increased risk of sole bruising but were associated with a reduced risk of skin abrasions and solid concrete floors without bedding was associated with an increased risk of sole erosion.

Chapter 7

Foot lesions in gilts and sows

7.1 Introduction

Examining live sow feet is difficult; therefore studies of prevalence of foot lesions commonly use culled sows. In samples of culled sows in the US and Norway, the prevalence of foot lesions was high; 59% of 11,175 sows and gilts (Ritter *et al.*, 1999), 86% of 3,158 sows (Knauer *et al.*, 2007) and 88% of 225 sows (Gjein and Larssen, 1995a). However, culled sows are a biased sample from the breeding population because foot lesions and lameness are a major reason for culling (Boyle *et al.*, 1998; Dewey *et al.*, 1993; Christensen *et al.*, 1995; Kirk *et al.*, 2005; Engblom *et al.*, 2007).

The types of lesion that occur on sows' feet are highly variable. Gjien and Larssen (1995a) classified lesions into six categories; wall lesions, heel lesions, overgrown heels, white line cracks, heel / sole junction cracks and toe cracks. Anil *et al.* (2007) used a similar system; classifying lesions by location on the wall, white line, heel, sole, toe and junction between heel and sole.

In rearing pigs, detailed studies have examined the associations between floor types and types of foot lesion. In the weaner and grower pigs from the farms in the current study, soft, deeply bedded floors were associated with the lowest prevalence of heel damage and the greatest prevalence of toe erosion. We hypothesised that toe erosion is associated with bedding because on soft floors wall horn becomes overgrown and the horn at the toe is then at risk of being eroded, perhaps on unbedded parts of the floor such as the edge of steps. It is also possible that sole horn at the toe might rot or flake away because of the wet conditions and contact with caustic slurry. Hard, slatted floors might be associated with heel flaps because they cause haemorrhage which creates pockets within the heel which as the horn grows and is worn away, presents as flaps of horn (Gillman *et al.*, submitted, Appendix D). Mouttotou *et al.* (1999c) and Scott *et al.*, (2007) reported similar associations between foot lesions and floor type in finishing pigs at slaughter.

Several studies have indicated that the prevalence of foot lesions is lower when the sow is restrained in a crate or stall (Kroneman *et al.*, 1993b; Gjein and Larssen, 1995c; Anil *et al.*, 2007), presumably the lack of mobility reduces the wear and tear on the feet. However, in a comparison of 34 Norwegian herds, Gjein and Larssen (1995c) reported that the overall lowest prevalence of foot lesions occurred in sows loose housed on solid concrete floors with deep straw bedding, compared with sows in stalls or loose housed on partly slatted floors.

Intrinsic factors may also affect the risk of a sow developing foot lesions. On a commercial farm in USA Anil *et al.* (2007) reported that sows with higher body condition score or higher back fat measurement were associated with an increased risk of foot lesions, perhaps due to the greater weight bearing pressure on the hooves. Pigmented breeds of pig with dark hooves might have a reduced risk of foot lesions, due to higher levels of mineral matter in the horn (Penny, 1979).

In this chapter the prevalence of foot lesions in over 2,700 gilts and sows is presented. The effect of breed, parity and indoor vs. outdoor housing on the prevalence of foot lesions is reported. Additionally, the effect of floor type and floor condition on the prevalence of foot lesions in maiden gilts and lactating sows is presented.

7.2 Materials and methods

7.2.1 Data collected

On each farm the hind left feet of 29 multiparious sows and five maiden gilts were examined (Chapter 2, Table 2.4). The pen that the maiden gilts were housed in indoors and the farrowing pens of four of the lactating sows were examined (Chapter 2, Table 2.7). The flooring risks associated with any-foot-lesion and individual foot lesions with prevalence greater than 5% were investigated in indoor maiden gilts and the lactating sows where the pen had been examined. The prevalence and risks for limb lesions in these lactating sows was presented in Chapter 5. The feet of gilts and pregnant sows were examined in different pigs from those whose limbs were examined in Chapter 4.

7.2.2 Sample of sows and gilts

A total of 2,714 pigs were examined. Out of this; 446 were gilts and 2,268 were sows, 1,065 sows were lactating and 1,203 were pregnant at the time of observation. Of the total 2,714; 2,469 were housed indoor and 245 were housed outdoors. Prevalence of foot lesions was calculated in 2,402 pigs from the ABP farms with complete data. Lactating sows were only examined indoors because it was not practical to examine lactating sows housed outdoors.

7.3 Results

7.3.1 Prevalence of lesions on the hind left foot of 397 gilts and 2,005 sows

The overall prevalence of foot lesions in sows was 70.7%; 32.1% had score one lesions, 29.0% had score two lesions and 9.6% had score three lesions. Overall 41.3% of sows had one lesion, 20.1% had two lesions and 9.2% had three or more lesions. The prevalence and severity varied by lesion type (Table 7.1 and Table 7.2).

Table 7.1: Number and percent of gilts and sows with foot lesions on the volar surface of the hind left foot

		Gilts n = 397		Sows n = 2005	
Lesion	Score	n	%	n	%
Toe erosion	Score 0	339	85.4	1499	74.8
	Score 1	48	12.1	275	13.7
	Score 2	9	2.3	201	10.0
	Score 3	1	0.3	30	1.5
	Toe erosion score 1-3	58	14.6	506	25.2
Heel / sole erosion	Score 0	341	85.9	1338	66.7
	Score 1	44	11.1	331	16.5
	Score 2	11	2.8	264	13.2
	Score 3	1	0.3	72	3.6
	Heel / sole erosion 1-3	56	14.1	667	33.3
Heel flap	Score 0	371	93.5	1655	82.5
	Score 1	21	5.3	173	8.6
	Score 2	4	1.0	133	6.6
	Score 3	1	0.3	44	2.2
	Heel flap score 1-3	26	6.5	350	17.5
Heel corrugation	Score 0	397	100.0	1869	93.2
	Score 1	0	0	87	4.3
	Score 2	0	0	38	1.9
	Score 3	0	0	11	0.5
	Heel corrugation score 1-3	0	0	136	6.8
Sole bruising	Score 0	392	98.7	2005	100.0
	Score 1	3	0.8	0	0
	Score 2	2	0.5	0	0
	Score 3	0	0.0	0	0
	Sole bruising score 1-3	5	1.3	0	0

Table 7.2: Number and percent of gilts and sows with overgrowth, white line lesions and wall damage on the hind left foot

Lesion type		Score	Gilts n = 397 n	%	Sows n = 2005 n	%
Overgrown	Both claws	Score 0	388	97.7	1861	92.8
		Score 1	9	2.3	70	3.5
		Score 2	0	0.0	46	2.3
		Score 3	0	0.0	28	1.4
	Both claw score 1-3		9	2.3	144	7.2
	One claw	Score 0	397	100.0	1888	94.2
		Score 1	0	0	76	3.8
		Score 2	0	0	31	1.5
		Score 3	0	0	10	0.5
	One claw score 1-3		0	0	117	5.8
	Overgrown score 1-3		9	2.3	241	12.0
Wall damage	Wall crack	Score 0	388	97.7	1912	95.4
		Score 1	9	1.3	39	1.9
		Score 2	0	0.8	39	1.9
		Score 3	0	0.3	15	0.7
	Wall crack score 1-3		9	2.3	93	4.6
	Wall bruise	Score 0	393	99.0	1971	98.3
		Score 1	3	0.8	28	1.4
		Score 2	0	0.0	5	0.2
		Score 3	1	0.3	1	0.0
	Wall bruise score 1-3		4	1.0	34	1.6
	Wall penetration	Score 0	392	98.7	1919	95.7
		Score 1	3	1.3	47	2.3
		Score 2	1	0.0	30	1.5
		Score 3	1	0.0	9	0.4
	Wall penetration score 1-3		5	1.3	86	4.3
	Wall damage score 1-3		16	4.0	181	9.0
White line lesion	White line crack	Score 0	396	99.7	1970	98.3
		Score 1	0	0.0	20	1.0
		Score 2	1	0.3	12	0.6
		Score 3	0	0.0	3	0.1
	White line crack score 1-3		1	0.3	35	1.7
	White line separation	Score 0	397	100.0	1926	96.1
		Score 1	0	0	43	2.1
		Score 2	0	0	28	1.4
		Score 3	0	0	8	0.4
	White line separation score 1-3		0	0	79	3.9
	White line lesion score 1-3		1	0.3	101	5.0

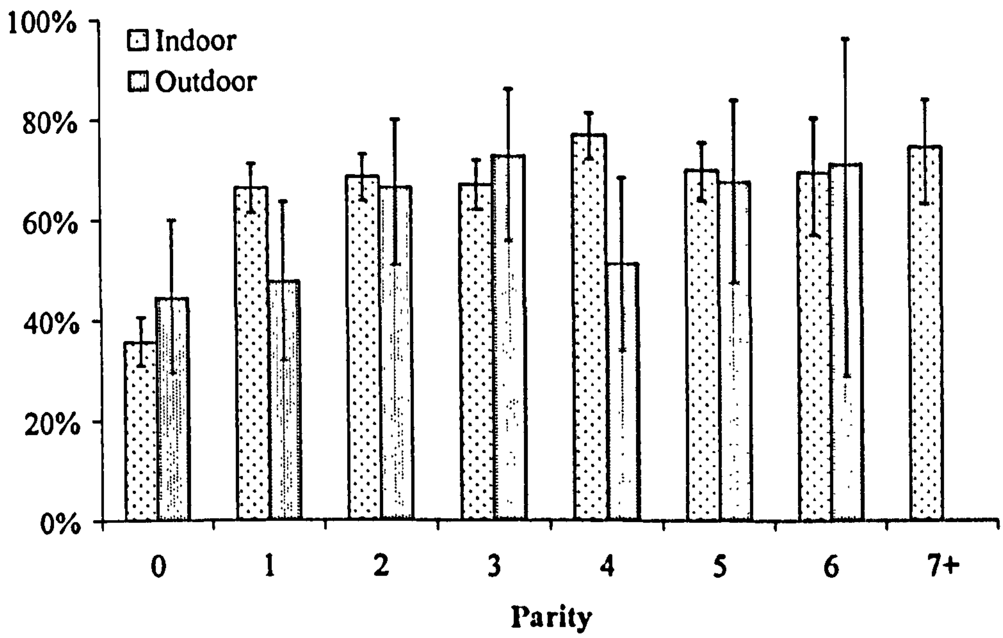
The prevalence of foot lesions in 397 maiden gilts was 37.0%; 28.0% had score one lesions, 7.8% had score two lesions and 1.3% had score three lesions. Overall 29.7% of maiden gilts had one foot lesion, 6.5% had two lesions and 0.3% had three lesions. The prevalence and severity of foot lesions in gilts varied by lesion type (Table 7.1 and Table 7.2). The three most prevalent lesions in gilts and sows were toe erosion, heel / sole erosion and heel flaps (Table 7.1).

7.3.2 Associations between prevalence of foot lesions and parity, breed line and reproductive stage of the sow

There was a reduced prevalence of any-foot-lesion (OR 0.3, CI 0.2, 0.4) and numerically all individual lesions (Table 7.3) in maiden gilts compared with multiparious sows. However, among multiparious sows there was no significant association between parity and the prevalence of any-foot-lesion ($p>0.05$) in indoor or outdoor housed sows (Figure 7.1). Numerically there also did not appear to be an association with parity with any of the individual lesion (Table 7.3).

Overall there was no significant difference in the prevalence of foot lesions between pregnant (71.1%) and lactating sows (70.1%) ($\chi^2 = 2.16$, df = 1, $p = 0.14$). However, when individual lesions were considered, pregnant sows had an increased prevalence of toe erosion (OR 1.3, CI 1.1, 1.8) and heel / sole erosion (OR 1.4, CI 1.1, 1.8) and a decreased risk of heel corrugation (OR 0.1, CI 0.1, 0.2) and heel flaps (OR 0.6, CI 0.5, 0.9), compared with lactating sows.

Figure 7.1: Percent of 2,296 indoor housed and 242 outdoor housed gilts and sows parity 1 – 7+ with any type of foot lesion on the hind left foot



Having controlled for the reproductive stage of the sow, there was a trend for a reduced prevalence of any-foot-lesion (OR 0.6, CI 0.4, 1.0) and a reduced prevalence of toe erosion (OR 0.6, CI 0.4, 1.0) and heel / sole erosion (OR 0.7, CI 0.4, 1.0) in pigmented pigs compared with non pigmented pigs. There was no significant difference (OR 0.5, CI 0.3, 1.0) between the prevalence of any-foot-lesion in outdoor housed sows (57%) compared with indoor housed sows (68%). When individual lesions were considered the only significant difference between prevalence in indoor and outdoor housed sows was for heel erosions (OR 0.4, CI 0.2, 0.7) (Table 7.3). When the data was split by parity there was a significant difference in prevalence of any-foot-lesion in 1st (χ^2= 5.9, df = 1, $p<0.05$) and 4th (χ^2= 11.1, df = 1, $p<0.05$) parity sows only.

Table 7.3: Number and percent of multiparious sows with foot lesions score 1-3 by parity, reproductive stage and breed line

	Any lesion		Overgrown claws		Wall damage		White line lesions		Toe erosion		Heel / sole erosion		Heel flap		Heel corrugation		Total n
Parity	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
1st	276	65.1	36	8.5	40	9.4	18	4.2	110	25.9	126	29.7	58	13.7	28	6.6	424
2nd	309	69.1	49	11.0	36	8.1	28	6.3	124	27.7	124	27.7	77	17.2	26	5.8	447
3rd	275	68.1	54	13.4	32	7.9	16	4.0	99	24.5	151	37.4	64	15.8	21	5.2	404
4th	295	75.3	66	16.8	40	10.2	20	5.1	122	31.1	135	34.4	81	20.7	16	4.1	392
5th	199	70.1	42	14.8	21	7.4	15	5.3	62	21.8	99	34.9	51	18.0	21	7.4	284
6th	51	71.8	12	16.9	6	8.5	4	5.6	16	22.5	22	31.0	12	16.9	2	2.8	71
7th plus	56	75.7	4	5.4	7	9.5	3	4.1	17	23.0	25	33.8	18	24.3	7	9.5	74
Reproductive stage																	
Lactating	716	108.5	140	21.2	104	15.8	44	6.7	221	33.5	303	45.9	214	32.4	112	17.0	660
Pregnant	865	54.7	152	9.6	96	6.1	65	4.1	357	22.6	448	28.3	177	11.2	29	1.8	1581
Breed line																	
Non pigmented	1061	74.1	219	15.3	115	8.0	78	5.5	415	29.0	532	37.2	233	16.3	76	5.3	1431
Pigmented	424	63.5	63	9.4	64	9.6	26	3.9	133	19.9	185	27.7	123	18.4	49	7.3	668
Indoor vs. outdoor																	
Indoor	1303	73.4	160	9.0	143	8.1	145	8.2	472	26.6	562	31.6	256	14.4	125	7.0	1776
Outdoor	124	62.0	11	5.5	15	7.5	0	0.0	29	14.5	44	22.0	42	21.0	11	5.5	200

7.3.3 Risks associated with lesions on the hind left foot of indoor housed lactating sows

7.3.3.1 Any-foot-lesion

The prevalence of foot lesions in lactating sows varied by floor type, body condition and breed line (Table 7.4). When all types of foot lesions were combined, there was a reduced risk of any-foot-lesion associated with lactating sows classified as pigmented compared with non pigmented. Sows with a body condition score of 3.5 or above had an increased risk of foot lesions compared with sows with a body condition of score 3. There was also a non significant trend for an increased risk of foot lesions in sows with a body condition score 2.0 or lower compared with sows with a body condition score of 3. There was no significant association between the prevalence of any-foot-lesion and week of lactation, floor type or use of bedding in the farrowing pen or the accommodation during pregnancy (Table 7.5).

7.3.3.2 Toe erosion

There was a decreased risk of toe erosion associated with slatted floors in the pregnant sow accommodation, compared with solid concrete floors with straw bedding. There was an increased risk of toe erosion associated with sharp slat edges or sharp protrusions at joins between surfaces on the farrowing pen floor (Table 7.5).

Table 7.4: Number and percent of foot lesions score 1-3 in lactating sows by week of lactation, breed line, floor type and floor material

	Any lesion		Overgrown claws		Wall damage		White line lesions		Toe erosion		Heel / sole erosion		Heel flap		Heel corrugation		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Week of lactation																	
1-week	47	75.8	5	8.1	8	12.9	5	8.1	14	22.6	21	33.9	13	21.0	4	6.5	62
2-week	50	76.9	14	21.5	2	3.1	4	6.2	13	20.0	27	41.5	7	10.8	8	12.3	65
3-week	41	80.4	9	17.6	4	7.8	1	2.0	18	35.3	17	33.3	9	17.6	9	17.6	51
4-week	36	75.0	9	18.8	1	2.1	1	2.1	5	10.4	23	47.9	9	18.8	4	8.3	48
Breed line																	
Non pigmented	139	80.3	30	17.3	14	8.1	5	2.9	42	24.3	70	40.5	41	23.7	17	9.8	173
Pigmented	34	65.4	6	11.5	1	1.9	6	11.5	8	15.4	18	34.6	7	13.5	8	15.4	52
Body condition score																	
≤ 2.0	12	80.0	2	13.3	0	0.0	0	0.0	4	26.7	4	26.7	2	13.3	8	53.3	12
2.5	46	76.7	9	15.0	6	10.0	4	6.7	12	20.0	29	48.3	13	21.7	12	20.0	46
3.0	72	72.7	14	14.1	5	5.1	5	5.1	19	19.2	40	40.4	20	20.2	5	5.1	72
≥ 3.5	42	85.7	11	22.4	4	8.2	2	4.1	15	30.6	15	30.6	12	24.5	0	0.0	42
Floor type																	
Solid with bedding	16	64.0	3	12.0	4	16.0	1	4.0	7	28.0	7	28.0	3	12.0	0	0.0	25
Partly slatted with bedding	39	79.6	2	4.1	5	10.2	3	6.1	6	12.2	23	46.9	10	20.4	4	8.2	49
Partly slatted no bedding	93	78.8	22	18.6	4	3.4	5	4.2	32	27.1	42	35.6	32	27.1	19	16.1	118
Fully slatted	25	75.8	9	27.3	2	6.1	2	6.1	5	15.2	16	48.5	3	9.1	2	6.1	33
Pregnant sow floor type																	
Solid concrete with bedding	150	76.5	32	16.3	12	6.1	8	4.1	48	24.5	78	39.8	37	18.9	19	9.7	196
Partly / fully slatted	23	79.3	4	13.8	3	10.3	3	10.3	2	6.9	10	34.5	11	37.9	6	20.7	29
Slat material																	
Metal	80	79.2	14	13.9	13	12.9	4	4.0	17	16.8	42	41.6	23	22.8	15	14.9	101
Plastic	75	78.9	20	21.1	9	9.5	6	6.3	24	25.3	36	37.9	20	21.1	10	10.5	95
Metal and plastic	7	70.0	0	0.0	0	0.0	0	0.0	2	20.0	6	60.0	2	20.0	1	10.0	10

Table 7.5: Two level logistic binomial models of the risks associated with the prevalence of foot lesions in indoor housed lactating sows

	Any-foot-lesion n = 250 sows		Overgrown n = 247 sows		Toe erosion n = 246 sows		Heel/ sole erosion n = 250 sows		Heel flap n = 251 sows		Wall damage n = 251 sows	
Intercept coefficient	0.8		-2.2		-0.2		-1.1		-1.9		-0.7	
	OR	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Week of lactation	0.9	0.7, 1.2	1.4	1.0, 1.9	0.9	0.6, 1.2	1.1	0.9, 1.4	0.9	0.7, 1.2	-0.7	0.4, 1.1
Breed line												
Non pigmented	1.0		1.0		1.0		1.0		1.0		1.0	
Pigmented	0.4	0.2, 0.9	0.6	0.2, 1.6	0.5	0.2, 1.3	0.6	0.3, 1.4	0.6	0.2, 1.5	0.2	0.0, 1.5
Lactation floor / bedding												
Solid concrete with bedding	1.0		1.0		1.0		1.0		1.0		1.0	
Partly slatted with bedding	2.1	0.6, 7.0	0.2	0.0, 1.3	0.6	0.2, 1.7	1.9	0.5, 7.1	1.3	0.3, 6.5	0.6	0.1, 2.9
Partly slatted no bedding	2.4	0.8, 7.3	1.4	0.4, 5.0	0.8	0.2, 2.5	1.4	0.4, 4.6	3.3	0.8, 14.4	0.3	0.1, 1.4
Fully slatted	2.3	0.6, 8.7	2.2	0.5, 9.0	0.3	0.1, 1.3	1.8	0.4, 7.1	1.7	0.3, 9.5	0.4	0.1, 2.8
Pregnant sow floor												
Solid concrete with bedding	1.0		1.0		1.0		1.0		1.0		1.0	
Partly / fully slatted	1.5	0.4, 5.4	1.2	0.3, 4.3	0.2	0.0, 0.9	0.7	0.2, 2.1	3.3	1.1, 9.8	1.1	0.2, 5.1
Sow body condition score												
≤2.0	2.1	0.6, 7.7										
2.5	1.3	0.6, 2.8										
3.0	1.0											
≥3.5	3.1	1.2, 8.3										
Wet floor on sow lying area												
No			1.0									
Yes			0.2	0.1, 0.9								
Sharp edges on sow lying area												
No												
Yes					3.9	1.0, 15.0						
Wet slurry on sow dunging area												
No												
Yes							2.2	1.1, 4.4				
Random effects	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**
Variation between farms	0.7	0.4	0.3	0.4	0.4	0.4	0.9	0.4	0.7	0.4	0.6	0.8
Hosmer-Lemeshow	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**	χ^2	**P value**
goodness-of-fit *df = 3, †df = 2	6.0	0.30	3.5*	0.47	4.0	0.42	11.0	0.06	15.0	<0.05	2.0†	0.37

7.3.3.3 Heel flaps

There was an increased risk of heel flaps associated with slatted floors in the pregnant sow accommodation compared with solid concrete floors with bedding.

7.3.3.4 Overgrown hooves and sole erosion

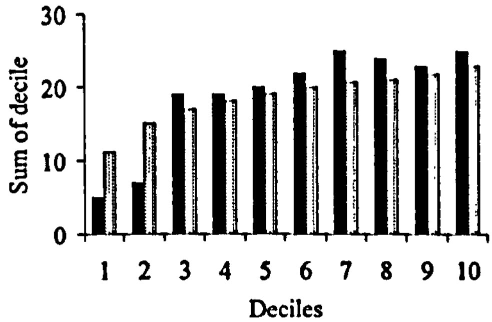
The risk of overgrown hooves increased with increasing week of lactation and reduced when the sow's lying area (all areas within the crate that were not the dunging area) in the farrowing pen was wet. There was an increased risk of sole erosion when there was a covering of wet slurry in the sows dunging area within the crate (Table 7.5).

7.3.3.5 Model fit and observer

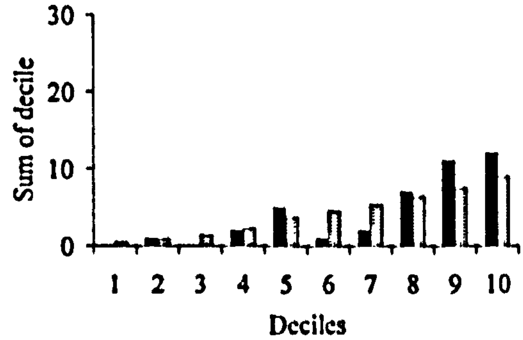
The Hosmer-Lemeshow goodness-of-fit statistic indicated that the difference between the observed and expected values for any-foot-lesion, wall damage, over growth or toe erosion were small. However, the difference between observed and predicted values for heel flap and erosion models was larger, indicating these models fitted to the data less well (Table 7.5 and Figure 7.2). Controlling for the identity of the observer in the models did not significantly alter the interpretation of any of the fixed effects.

Figure 7.2: Graphs a - f of observed verses predicted values from logistic binomial regression models for foot lesion models in lactating sows

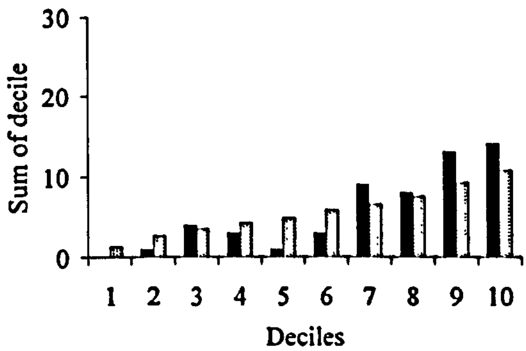
a. Any-foot-lesion



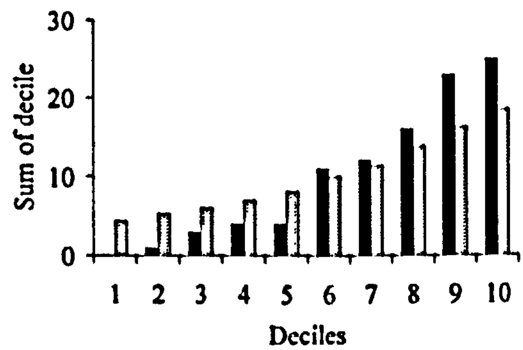
b. Overgrown



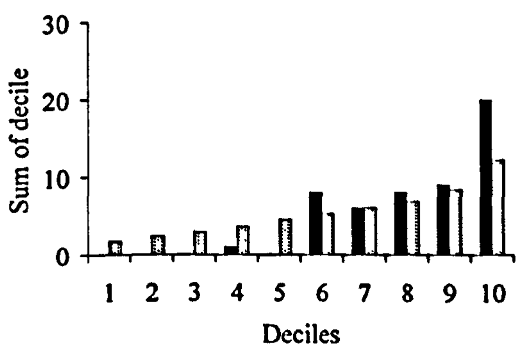
c. Toe erosion



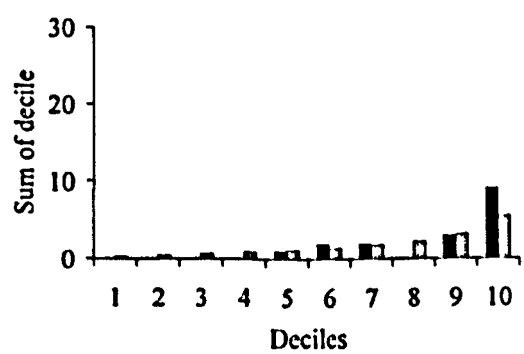
d. Heel / sole erosion



e. Heel flap



f. Wall damage



7.3.4 Risks associated with lesions on the hind left foot of indoor housed maiden gilts

7.3.4.1 Any lesion

There were no significant differences in the prevalence of any-foot-lesion (OR 1.4, CI 0.7, 3.1) or individual foot lesions (Table 7.6, models not shown) between indoor and outdoor housed gilts. There was no significant effect of indoor floor type on the prevalence of any-foot-lesion in gilts. (Table 7.7).

7.3.4.2 Toe erosion

None of the pigs housed on slatted floors or solid concrete floors with sparse bedding in the lying area had toe erosion. In the models comparing indoor floor types excluding these floors, there were no significant differences in the prevalence of toe erosion associated with floor type (Table 7.7).

7.3.4.3 Heel flaps

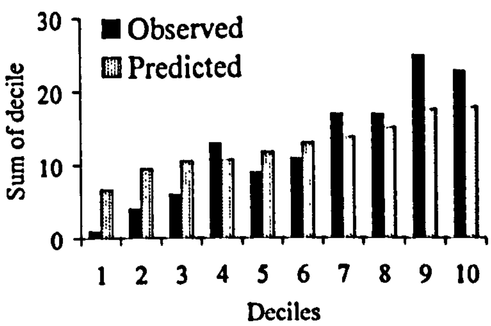
There was an increased risk of heel flaps in gilts on solid concrete floors with deep bedding in the lying area only (Table 7.7).

7.3.4.4 Model fit and observer

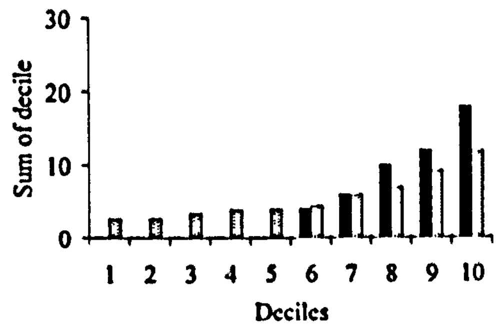
As for lactating sows, the Hosmer-Lemeshow goodness-of-fit statistic indicated that the greatest difference between the observed and predicted values occurred in the gilt heel flap and erosion models (Table 7.7). Generally observed values increased with the predicted values, but there was a trend for over prediction in the low deciles (Figure 7.3). Controlling for the identity of the observer in the models did not significantly alter the interpretation of any of the fixed effects.

Figure 7.3: Graphs a – d of observed verses predicted values from logistic binomial regression models for foot lesions in maiden gilts

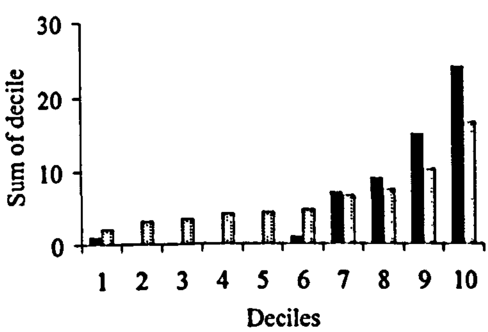
a. Any lesion



b. Toe erosion



c. Heel / sole erosion



d. Heel flap

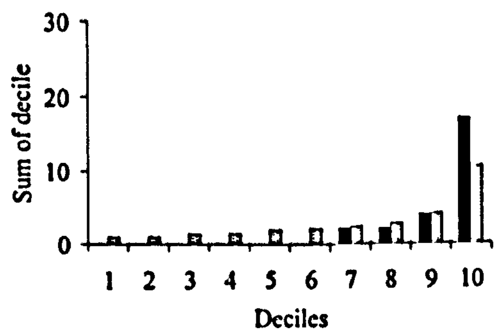


Table 7.6: Number and percent of foot lesions score 1-3 in maiden gilts by floor type, observations of slipping and breed line

	Any lesion		Overgrown claws		Wall damage		White line lesions		Toe erosion		Heel / sole erosion		Heel flap		Sole bruise		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Floor type																	
Solid deep bedding all areas	31	37.3	3	3.6	1	1.2	1	1.2	16	19.3	14	16.9	2	2.4	0	0.0	83
Solid deep / sparse bedding all areas	31	35.6	0	0.0	6	6.9	2	2.3	14	16.1	11	12.6	4	4.6	0	0.0	87
Solid sparse bedding all areas	23	33.8	2	2.9	1	1.5	0	0.0	9	13.2	10	14.7	3	4.4	2	2.9	68
Solid deep bedding in lying area	17	48.6	0	0.0	1	2.9	0	0.0	5	14.3	5	14.3	6	17.1	2	5.7	35
Solid sparse bedding in lying area	6	30.0	0	0.0	2	10.0	0	0.0	0	0.0	1	5.0	2	10.0	1	5.0	20
Slatted	11	34.4	4	12.5	1	3.1	0	0.0	0	0.0	6	18.8	3	9.4	0	0.0	32
Outdoor	23	40.4	0	0.0	3	5.3	0	0.0	11	19.3	8	14.0	6	10.5	0	0.0	57
Pigs observed slipping																	
No	72	34.8	2	1.0	4	1.9	1	0.5	38	18.4	24	11.6	13	6.3	2	1.0	207
Yes	60	45.8	4	3.1	11	8.4	2	1.5	16	12.2	25	19.1	11	8.4	3	2.3	131
Breed line																	
Non pigmented	95	36.7	6	2.3	10	3.9	2	0.8	41	15.8	30	11.6	16	6.2	3	1.2	259
Pigmented	47	38.2	3	2.4	4	3.3	1	0.8	15	12.2	25	20.3	10	8.1	2	1.6	123

Table 7.7: **Two level logistic binomial models of the risks associated with the prevalence of foot lesions in maiden gilts**

	Any lesion (n = 382 gilts)		**Toe erosion** (n = 317 gilts)		**Heel / sole erosion** (n = 426 gilts)		**Heel flap** (n = 431 gilts)	
Intercept coefficient	-0.3		-1.5		-1.6		-3.4	
	OR	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Floor type								
Solid deep bedding all areas	1.0		1.0		1.0		1.0	
Solid deep / sparse bedding all areas	0.6	0.2, 1.3	1.0	0.4, 2.7	0.7	0.2, 1.9	1.4	0.3, 21.5
Solid sparse bedding all areas	0.7	0.3, 1.5	0.6	0.2, 1.6	1.1	0.4, 2.9	2.3	0.5, 21.9
Solid deep bedding in lying area	1.2	0.4, 3.7	0.8	0.2, 2.9	0.8	0.2, 3.3	6.3	1.1, 34.7
Solid sparse bedding in lying area	0.4	0.1, 1.2	None	affected	0.2	0.0, 2.0	2.6	0.3, 10.8
Slatted	0.5	0.1, 1.4	None	affected	1.2	0.3, 4.5	3.3	0.5, 7.5
Pigs observed slipping								
No	1.0							
Yes	1.7	1.0, 3.2						
Random effects	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**	**Var.**	**SE**
Variation between farms	0.4	0.2	0.9	0.4	1.0	0.4	1.1	0.7
Hosmer-Lemeshow goodness-of-fit	**χ^2**	**P value**	**χ^2**	**P value**	**χ^2**	**P value**	**χ^2**	**P value**
*df = 3	6.0	0.12	6.0	0.31	18.9	0.02	8.1*	<0.05

7.3.5 Associations between foot lesions in pregnant and lactating sows

Overgrown hooves were positively associated with wall damage, white line lesion, toe erosion and heel and sole erosion. Wall damage was positively associated with white line lesion and heel corrugation. Heel / sole erosion was positively associated with white line lesion and toe erosion. There was a negative association between toe erosion and heel flaps and between heel corrugation and heel / sole erosion (Table 7.8). However, many of these lesions were correlated at a very low level.

Table 7.8: Associations between foot lesions in 2,241 pregnant and lactating sows

	Over grown	Wall damage	White line	Toe erosion	Heel / sole erosion	Heel flap
Overgrowth	1.00					
Wall damage	0.04*	1.00				
White line	0.04*	0.07*	1.00			
Toe erosion	0.20*	0.00	0.03	1.00		
Heel / sole erosion	0.11*	0.03	0.06*	0.08*	1.00	
Heel flap	-0.04	-0.02	0.01	-0.06*	-0.03	1.00
Heel corrugation	0.02	0.06*	0.01	0.00	-0.05*	0.00

* $p<0.05$

7.3.6 Associations between limb, body and foot lesions in lactating sows

The prevalence of limb and body lesions in the subset of lactating sows examined in detail was reported in Chapter 5. Toe erosion was positive correlated with wounds on the limbs ($r = 0.12$, $df = 253$, $p<0.05$). White line lesions were positively correlated with new lesions on the shoulder ($r = 0.16$, $df = 253$, $p<0.05$) and the hip, spine or tail ($r = 0.24$, $df = 253$, $p<0.05$). Heel / sole erosion was also positively correlated with new lesions on the hip, spine or tail ($r(253) = 0.14$, $p<0.05$)

7.3.7 Associations between foot lesions in maiden gilts

There were no significant associations between foot lesions in maiden gilts (Table 7.9) and the patterns of association did not follow those in multiparious sows (Table 7.8)

Table 7.9: Associations between foot lesions in 446 maiden gilts

	Over grown	Wall damage	White line lesion	Toe erosion	Heel / sole erosion	Heel flap
Overgrown	1.00					
Wall damage	-0.03	1.00				
White line lesion	-0.01	-0.02	1.00			
Toe erosion	-0.05	-0.02	0.02	1.00		
Heel / sole erosion	-0.02	0.00	-0.04	0.04	1.00	
Heel flap	-0.04	-0.01	-0.02	-0.01	0.07	1.00
Sole bruising	-0.01	-0.02	-0.01	-0.04	-0.04	-0.03

7.4 Discussion

This study provides, to date, the most accurate measure of the prevalence of foot lesions in live gilts and multiparious sows in England. One of the difficulties of collecting accurate observational data on the prevalence of foot lesions in gilts and sows is the large number of different lesions that occur. The scoring system used in this study was highly detailed to allow the variation in lesions to be accurately recorded, which is important because they might have different aetiology. However, the problem with collecting such detailed data was that the prevalence of some lesions was very low and a very large sample size would have been required to have sufficient power to identify significant risks for these individual lesions. Therefore, by necessity, some of the lesions were combined.

Although differences in sample and scoring systems between studies make exact comparisons difficult, the patterns broadly agree with previous work for the overall prevalence (Gjein and Larssen, 1995a; Ritter *et al.*, 1999: Anil *et al.*, 2007; Knauer *et al.*, 2007) and the most prevalent lesions types (Anil *et al.*, 2007; Knauer *et al.*, 2007). The pattern of prevalence of different types of lesions is also similar to the weaning and grower pigs from the farms in the current study; where heel flaps, heel / sole erosion and toe erosion were also the three most prevalent lesions (Gillman *et al.*, submitted, Appendix D).

The current study is the first to compare the prevalence of foot lesions in a cross sectional sample of indoor and outdoor housed sows. One major finding was that foot lesions were highly prevalent (57%) in outdoor housed sows and gilts and non significantly less prevalent than in indoor housed sows and gilts (68%). It may be that outdoor housed pigs are at risk of foot lesions because their feet become soft in overly wet conditions (Barnett *et al.*, 1984) or because many paddocks are stony (Chapter 2, Table 2.17). Standing on stones might be associated with the prevalence of heel flaps in outdoor housed sows, as the pathology of these lesions indicates they are associated with haemorrhage within the heel, these were the only lesion that was more prevalent outdoors than indoors. While outdoor housing appears to be an ideal environment to minimise the risk of limb lesions, this does not appear to be the case for foot lesions in gilts and sows.

There was some indication that there was a difference between indoor and outdoor housed pigs in the manner in which prevalence of foot lesions increased with parity. In indoor housed gilts the prevalence of foot lesions increased sharply during their first gestation. A similar pattern was reported by Kroneman *et al.* (1993b) in 30 indoor housed gilts. However, in outdoor housed gilts the prevalence increased more slowly over parities one to three. The rapid increase in indoor housed gilts may be associated with housing in farrowing crates, which are commonly slatted and used with little bedding. Alternatively, other management or breed differences may explain the divergence between indoor and outdoor gilts. To investigate the risks associated with foot lesions in outdoor housed gilts and sows more fully, a larger cohort study would be required.

The impact of floor type in indoor gilt and pregnant sow accommodation was similar to the findings from previous work in rearing pigs from these herds and previous studies of finishing pigs at slaughter (Mouttotou *et al.*, 1999c ; Scott *et al.*, 2006; Gillman *et al.*, submitted, Appendix D); solid floors with bedding were associated with a high prevalence of toe erosion and slatted floors with a high prevalence of heel flaps. Overall, there does not appear to be an ideal indoor floor type that minimised the risk of all types of foot lesion in pigs. However, what is unclear at this stage is whether the pathology of different lesions is of comparable discomfort. The small pathology study carried out on the weaner and grower pigs in the current study, suggests that heel flaps arise from haemorrhaging within the sole, which is likely to be associated with discomfort (Gillman *et al.*, submitted, Appendix D). Other lesions, such as toe erosion, must now be investigated to identify the likely degree of pain or discomfort associated with the pathology.

It was interesting to note that it was the floor type the sow had been housed on during pregnancy, rather than the farrowing pen floor that they were currently housed on, that was primarily associated with the prevalence of foot lesions in lactating sows. It might be that the flooring during pregnancy had a greater effect because the pigs are mobile during this stage, or because there is a lag between exposure to a floor type and development of lesions (Gjein and Larssen, 1995c). In the current study, while the prevalence of certain lesions decreased with week of lactation, overall, being restrained in the farrowing crate did not reduce the prevalence of foot lesions as was reported by Kroneman *et al.* (1993b). This may be due to differences in both the gestation and lactation floor between the current study and the Kroneman study and severity of lesions recorded.

However, the condition of the farrowing pen floor, that is, how wet and dirty it was, was associated with the prevalence of foot lesions in lactating sows. It is possible that sows' feet were more likely to be eroded and worn down (reduced risk of overgrowth) when the farrowing pen floor was covered with liquid or slurry because it softened the horn, because of the acidic caustic nature of slurry or because it made the floor more slippery and this increased the wear on the hoof (Kronegay and Lindemann, 1984; Kroneman *et al.*, 1993a; Gjein and Larssen, 1995c). In the current study weaner and grower pigs in pens where slipping was observed also had an increased risk of foot lesions (Gillman *et al.* submitted, Appendix D).

As reported in previous studies (Anil *et al.*, 2007; Knauer *et al* 2007), sows that were carrying more weight had an increased risk of foot lesions. However, there was also a trend for an increased prevalence of foot lesions in sows that were thinner than average. It may be that nutritional deficiencies increased the risk of foot lesions (Webb *et al.*, 1984) or that sows may lose condition if experiencing discomfort associated with foot lesions.

Sows that were classified as pigmented, that is with Duroc, Pietrain or Hampshire in their breeding, were less likely to have foot lesions. A similar pattern was reported in weaner and grower pigs from these farms (Gillman *et al.*, submitted, Appendix D). It has been hypothesised that pigmented breeds have harder horn (Penny, 1979). However, there was no effect of breed line in maiden gilts in the current study.

Broadly, the pattern of prevalence and the risks associated with foot lesions were similar between maiden gilts and sows. However, the maiden gilt models were a poor fit to the data and few variables were significantly associated with the outcomes. It may have been more difficult to predict the prevalence of foot lesions in maiden gilts because they had been introduced into the breeding herd only a short time before, and their previous housing was unknown. The maiden gilt models also had less statistical power than the lactating sow models both because of the lower prevalence of foot lesions and because only one pen of maiden gilts was examined on each farm.

Although 29.3% of sows and 6.8% of gilts had more than one lesion, apart from the association between toe erosion and overgrown hooves mentioned above, foot lesions were generally not strongly correlated suggesting, they were distinct lesions with differing actiologies. In lactating sows there was a positive association between toe erosion and wounds on the limbs. This association might arise because these lesions occur as feet or limbs are caught on sharp or abrasive parts of the pen floor. Sows might also be at particular risk of these lesions when they have been housed in a soft environment during pregnancy where their hooves become overgrown and their skin is soft. It is possible that body lesions are associated with white line lesions and heel / sole erosion because these foot lesions cause discomfort when standing and therefore the sow spends more time lying or because these lesions both occur in larger sows which are heaver and older and have less space within the crate.

7.4.1 Conclusion

The prevalence of foot lesions in sows and gilts in English pig herds housed both indoors and outdoors is high, but each lesion type has a relatively low prevalence. No one floor type was clearly associated with the lowest prevalence of all types of foot lesion. Further research is required to determine which foot lesions, and therefore which floor types, are most costly to the sow and producer in terms of discomfort, lameness and increased risk of premature culling.

Chapter 8

Lameness in finishing pigs, gilts and sows

8.1 Introduction

Lameness is characterised by a deviation from normal gait and posture. Lameness can be an indication that the animal is experiencing pain or discomfort when standing and walking and as such is an obvious welfare concern. Additionally, lameness may be costly to the producer. Lame finishing pigs have been reported to have a reduced daily weight gain compared with sound pigs (Jensen *et al.*, 2007). Lameness is the third most common reason for treatment for disease in finishing pigs and accounts for 11% of all treatments given (Christensen *et al.*, 1994). In breeding sows, lameness is one of the major reasons for premature culling; accounting for 9-13% of premature sow culling worldwide (Boyle *et al.*, 1998; Lucia *et al.*, 2000; Anil *et al.*, 2005; Engblom *et al.*, 2007).

In Scotland, Smith and Morgan (1997) reported a prevalence of lameness of 4% in 15,540 finishing pigs at slaughter. In a similar study at slaughter in Switzerland 2% of 2,192 pigs from 107 herds were lame (van den Berg *et al.*, 2007). While Krieter *et al.* (2004) reported a prevalence of lameness of less than 1% in finishing pigs on a cross-sectional study of 97 farms in Switzerland.

The prevalence of lameness in sows and gilts is generally reported to be higher than in finishing pigs. In 1,436 pregnant sows and gilts from 15 herds in Norway Gjein and Larssen (1995b) reported a prevalence of lameness of 13.1%.

Elsewhere, Heinonen *et al.* (2006) reported a prevalence of 8.8% in 646 pregnant sows and gilts from 21 herds in Finland. While in 555 lactating sows from 10 Danish herds, Bonde *et al.* (2004) reported that 15% were lame. Smith and Morgan (1997) noted that lameness is a common reason for rejection of gilts for breeding and reported that on a single multiplier unit 15% of 4,993 of gilts were rejected as unsound.

Lameness can have many causes, with infectious arthritis or non infectious degeneration of the cartilage and bone of the joint (osteochondrosis) the most common (Dewey *et al.*, 1993; Jorgensen *et al.*, 1995; Kirk *et al.*, 2005). Traumatic damage to the limb or foot may also cause lameness (Smith, 1988). At post-mortem examination of sows culled due to lameness, lesions in the foot were determined to be the cause of lameness in 5% of 35 sows in Denmark (Kirk *et al.*, 2005) and 20% of 50 sows in Canada (Dewey *et al.*, 1993). The strength of association between foot lesions and lameness may depend on the severity (Gjein and Larssen, 1995b) of the lesions and the part of the foot affected (Anil *et al.*, 2007), but not all studies have detected a significant association (Kroneman *et al.*, 1993b). In lactating sows Bonde *et al.* (2004) reported low body condition and wounds on the limbs were also associated with lameness. While von Berner *et al.* (1990) reported bursitis on the hind limbs was associated with 'false posture' and claw and joint abnormalities in 270 sows from two farms.

The prevalence of lameness may be associated with the floor type on which the pig is housed. In over 4,000 finisher pigs on an experimental unit, Scott *et al.* (2006) reported a higher prevalence of treatment for lameness in pigs housed on concrete fully slatted floors compared with solid concrete floors with bedding. Jorgensen (2003) reported a trend for an increased risk of abnormal posture and gait among 300 finishing pigs housed on fully slatted floors compared with solid concrete floors with or without bedding. In gilts and sows, an increased risk of lameness was reported in pigs housed on slatted floors compared with solid concrete floors with bedding (Heinonen *et al.*, 2006). However, in two large cross-sectional studies of 84 (Cagienard *et al.*, 2005) and 97 (Krieter *et al.*, 2004) farms in Switzerland, the prevalence of lameness was lower in finishing pigs housed in fully slatted finishing pens compared with straw bedded pens. In a small experimental study Barnett *et al.* (1984) suggested that sows housed outdoors may have a reduced prevalence of lameness. However, Cox and Bilkei (2004) reported a higher prevalence of culling for lameness in 17 outdoor housed herds compared with 27 indoor housed herds in a cross sectional study in Croatia.

Floor type is commonly correlated with stocking density, with pigs more tightly stocked on slatted floors and floors with no bedding. As such it is often difficult to separate an effect of stocking density from an effect of floor type (Smith and Morgan, 1997; Scott *et al.*, 2006; Zurbrigg and Blackwell, 2006). Having controlled for the effect of floor type in 300 finishing pigs, Jorgensen (2003) reported an increased risk of abnormal posture and gait in the most tightly stocked pigs. Two studies of sows have reported no effect of stocking density on the prevalence of lameness (Gjein and Larssen, 1995b; Heinonen *et al.*, 2006).

In this chapter, the prevalence of abnormal locomotion in finishing pigs, gilts and pregnant sows and abnormal posture in lactating sows in presented. Additionally, associations with floor type, limb lesions, and foot lesions in lactating sows, are investigated.

8.2 Materials and methods

8.2.1 Data collected

On each farm, two ages of finishing pigs (18-22 weeks old), maiden gilts, pregnant gilts and pregnant sows were examined for lameness and the standing posture of crated lactating sows was assessed. Lameness and posture was scored using a modification of the system devised by Main *et al.* (2000) (Chapter 2, Table 2.6). As presented in Chapters 3, 4, and 5, calluses, bursitis and capped hock on the limbs were scored one to three by size (Chapter 2, Table 2.3). As presented in Chapter 7, foot lesions in lactating sows were defined and scored one to three by severity (Chapter 2, Table 2.4). The floor type, floor condition and bedding that the pigs were housed on was recorded (Chapter 2, Table 2.7). The floor types, limb lesions and in lactating sows, foot lesions, associated with abnormal gait and posture were investigated in binomial logistic and multinomial multilevel regression models (for more detail see Chapter 2, section 2.13). Outdoor housed finishing pigs were excluded from the multinomial analysis due to the small numbers.

8.2.2 Sample of pigs

A total of 4,275 pigs were examined; 1,623 finishing pigs, 801 maiden gilts, 744 pregnant gilts, 866 pregnant sows and 241 lactating sows, 703 were housed outdoor and 3,572 were housed indoors. Prevalence was calculated in 3,860 pigs from the ABP English farms.

8.3 Results

8.3.1 Prevalence of limb lesions in finishing pigs, gilts and sows

The prevalence of limb lesions in maiden gilts, pregnant gilts, pregnant sows and lactating sows has been presented in Chapters 4 and 5. The prevalence of calluses, bursitis and capped hock in 1370 finishing pigs was 47.0%, 56.3% and 30.3% respectively (Table 8.1).

Table 8.1: Number and percent of 1,370 finishing pigs with limb lesions by score

	Calluses		Bursitis		Capped hock	
Score	n	%	n	%	n	%
0	727	53.1	599	43.7	956	69.8
1	263	19.2	275	20.1	260	19.0
2	287	21.0	343	25.0	131	9.6
3	93	6.8	153	11.2	23	1.7

8.3.2 Prevalence of lameness in 3,860 finishing pigs, gilts and sows

Overall, 4.8% of pigs had an abnormal response to human presence, 2.1% exhibited abnormal behaviour within the group, 7.3% had an abnormal standing posture and 16.5% had abnormal gait (as defined by Main *et al.*, 2000). The prevalence of these outcomes varied by the age or stage of the pig as detailed in (Table 8.2).

Table 8.2: Number and percent of finishing pigs, gilts and sows with lameness scored 0 - 5

		Finisher pigs		Maiden gilts		Pregnant gilts		Pregnant sows		Lactating sows	
	Score	n	%	n	%	n	%	n	%	n	%
Initial response to human presence*	0	1342	98.0	662	97.9	590	96.7	695	96.3	155	64.3
	1	13	0.9	6	0.9	12	2.0	6	0.8	68	28.2
	2	5	0.4	3	0.4	1	0.2	4	0.6	18	7.5
	3	4	0.3	4	0.6	7	1.1	15	2.1	0	0.0
	4	2	0.1	0	0.0	0	0.0	2	0.3	0	0.0
	5	4	0.3	1	0.1	0	0.0	0	0.0	0	0.0
	Total 1 -5	28	2.0	14	2.1	20	3.3	27	3.8	86	35.7
Behaviour within the group*	0	1342	98.0	660	97.6	593	97.2	710	98.3	Not applicable	
	1	9	0.7	6	0.9	9	1.5	3	0.4		
	2	11	0.8	7	1.0	6	1.0	9	1.2		
	3	3	0.2	2	0.3	2	0.3	0	0		
	4	2	0.1	0	0.0	0	0.0	0	0		
	5	3	0.2	1	0.1	0	0.0	0	0		
	Total 1 -5	28	2.0	16	2.4	17	2.8	12	1.7		
Posture*	0	1255	91.6	635	93.9	578	94.8	670	92.8	218	90.4
	1	43	3.1	24	3.6	15	2.5	25	3.5	20	8.3
	2	56	4.1	14	2.1	11	1.8	18	2.5	0	0.0
	3	10	0.7	1	0.1	3	0.5	9	1.2	2	0.8
	4	2	0.1	1	0.1	3	0.5	0	0	0	0.0
	5	4	0.3	1	0.1	0	0.0	0	0	1	0.4
	Total 1 -5	115	8.4	41	6.1	32	5.2	52	7.3	23	9.5
Gait*	0	1100	80.3	596	88.2	522	85.6	600	83.1	Not scored	
	1	182	13.3	61	9.0	65	10.7	75	10.4		
	2	69	5.0	15	2.2	14	2.3	34	4.7		
	3	11	0.8	2	0.3	7	1.1	12	1.7		
	4	3	0.2	1	0.1	2	0.3	1	0.1		
	5	5	0.4	1	0.1	0	0.0	0	0		
	Total 1 -5	270	19.7	80	11.8	88	14.4	122	16.9		
Total n			1370	676		610		722		241	

* see Chapter 2, Table 2.6 for lameness score definitions

8.3.2.1 Associations between behavioural indicators of lameness

Responsiveness to humans, behaviour within the group, standing posture and gait were positively correlated in finishing pigs, gilts and pregnant sows (Table 8.3). These associations did not differ when the data were analysed by type of pig (data not presented). Responsiveness to humans and standing posture were positively correlated in lactating sows ($r = 0.3$, $df = 241$, $p < 0.05$). Among pregnant sows with abnormal gait only 40% had abnormal posture.

Table 8.3: Correlations between behavioural indicators of lameness in 4,034 finishing pigs, gilts and sows

	Human presence	Behaviour within the group	Standing posture	Gait
Human presence	1.0			
Behaviour within the group	0.7*	1.0		
Standing posture	0.5*	0.6*	1.0	
Gait	0.4*	0.5*	0.7*	1.0

* $p < 0.05$

Because the behavioural measures of lameness were strongly correlated; gait, or posture in the case of lactating sows, was used as the outcome variable in further analysis. The prevalence of abnormal gait in finishing pigs, maiden gilts, pregnant gilts and pregnant sows was 19.7%, 11.8%, 14.4% and 16.9% respectively and varied by age / stage, floor type, limb lesions and stocking density (Table 8.4). The prevalence of abnormal posture in indoor housed lactating sows was 10.8%. However; none of the 30 outdoor housed sows had abnormal posture. Prevalence of abnormal posture in lactating sows varied by indoor floor type, week of lactation and presence of limb (Table 8.5) and foot lesions (Table 8.6).

Table 8.4: Number and percent of finishing pigs, gilts and pregnant sows with abnormal gait by age/ stage, floor type, limb lesions and stocking density

	Finishing pigs			Gilts			Pregnant sows		
			Total			Total			Total
	n	%	n	n	%	n	n	%	n
Age / stage									
18-weeks	119	18.9	631						
22-weeks	116	19.8	587						
Maiden gilts				84	11.5	731			
Pregnant gilts				92	14.0	656			
Floor type									
Solid deep bedding all areas	6	5.0	121	33	12.3	268	17	13.9	122
Solid deep / sparse bedding all areas	24	9.1	264	31	9.5	326	46	18.3	252
Solid sparse bedding all areas	40	22.3	179	39	14.7	265	15	24.2	62
Solid deep bedding in lying area				15	11.6	129	7	11.9	59
Solid sparse bedding in lying area				8	11.1	72	3	6.8	44
Slatted* partly	49	16.9	290	14	18.9	21	21	44.7	44
fully	115	34.3	335						
Outdoor	1	3.4	29	36	14.2	253	13	10.3	126
Callus on limb									
Score 0	63	10.1	624	75	42.6	811	38	11.3	336
Score 1	43	18.6	231	49	27.8	333	28	19.7	142
Score 2	84	30.7	274	39	22.2	191	39	24.2	161
Score 3	45	50.6	89	13	7.4	52	17	24.3	70
Bursa on limb									
Score 0	51	9.9	514	121	12.6	957	66	13.8	477
Score 1	42	17.8	236	29	11.0	264	25	21.0	119
Score 2	92	28.8	320	23	15.9	145	25	25.3	99
Score 3	50	33.8	148	3	14.3	21	6	42.9	14
Capped hock on limb									
Score 0	135	16.1	837	109	11.7	935	61	15.7	388
Score 1	58	25.1	231	43	13.1	328	34	18.3	186
Score 2	34	26.8	127	24	20.9	115	23	19.3	119
Score 3	8	34.8	23	0	0.0	9	4	25.0	16
Average m^2/pig									
Category 1 - $0.5m^2$	34	15.1	225						
Category 2 - $0.7m^2$	164	33.5	490						
Category 3 - $1.0m^2$	123	16.6	741						
Category 4 - $1.2m^2$	156	15.7	996						
Category 5 - $1.8m^2$	195	15.5	1260						

* Pens with partly and fully slatted floors are combined for gilts and sows due to small numbers

Table 8.5: Number and percent of lactating sows with abnormal posture by week of lactation, floor type and slat material and lesions on the limbs

		Abnormal posture		Total n
		n	%	
Week of lactation				
1-week		7	13.2	53
2-week		8	14.3	56
3-week		3	6.7	45
4-week		4	8.2	49
Floor type				
Outdoor		0	0.0	30
Solid with bedding		2	9.1	22
Partly slatted with bedding		6	14.3	42
Partly slatted no bedding		7	6.4	110
Fully slatted		7	24.1	29
Gestation floor type				
Solid concrete with bedding		17	9.3	183
Part / fully slatted		5	25.0	20
Slat material				
Metal		9	10.6	85
Plastic		9	11.3	80
Metal and plastic		1	10.0	10
Limb lesions				
Callus on limb	Score 0	14	8.7	161
	Score 1	4	14.8	27
	Score 2	3	25.0	12
	Score 3	1	50.0	2
Wound on limb	Score 0	1	6.7	15
	Score 1	1	3.3	30
	Score 2	7	8.5	82
	Score 3	13	17.6	74
Bursa on limb	Score 0	16	13.0	123
	Score 1	2	6.3	32
	Score 2	3	8.8	34
	Score 3	1	7.1	14
Capped hock on limb	Score 0	6	9.7	62
	Score 1	6	8.5	71
	Score 2	9	15.0	60
	Score 3	1	10.0	10
Shoulder lesion	Score 0	14	9.0	156
	Score 1	4	28.6	14
	Score 2	1	11.1	9
	Score 3	0	0.0	1
Hip, spine or tail lesion	Score 0	14	8.8	160
	Score 1	3	25.0	12
	Score 2	2	28.6	7
	Score 3		0.0	1

Table 8.6: Number and percent of lactating sows with abnormal posture by foot lesion score 0-3

Lesion	Score	Abnormal posture n	%	Total n
Any-foot-lesion	Score 0	0	0.0	41
	Score 1	8	8.8	91
	Score 2	7	17.9	39
	Score 3	4	33.3	12
Overgrown	Score 0	14	9.2	152
	Score 1	2	8.3	24
	Score 2	0	0.0	2
	Score 3	3	60.0	5
Wall damage	Score 0	19	10.9	174
	Score 1	0	0.0	7
	Score 2	0	0.0	1
	Score 3	0	0.0	1
White line lesion	Score 0	17	9.8	174
	Score 1	0	0.0	4
	Score 2	2	66.7	3
	Score 3	0	0.0	2
Toe erosion	Score 0	13	9.4	138
	Score 1	1	3.2	31
	Score 2	3	30.0	10
	Score 3	2	50.0	4
Heel / sole erosion	Score 0	3	2.8	106
	Score 1	9	17.3	52
	Score 2	6	27.3	22
	Score 3	1	33.3	3
Heel flap	Score 0	15	10.3	146
	Score 1	4	14.8	27
	Score 2	0	0.0	10
	Score 3	0	0.0	0
Heel corrugation	Score 0	18	11.0	164
	Score 1	0	0.0	13
	Score 2	1	25.0	4
	Score 3	0	0.0	2

8.3.3 Logistic regression analysis of the risks associated with abnormal gait

8.3.3.1 Finishing pigs

Outdoor housed finisher pigs had the lowest prevalence of abnormal gait among finishing pigs in the different housing systems examined. However, the difference between the prevalence of abnormal gait in outdoor housed finisher pigs compared with indoor housed finisher pigs was not significantly different (OR 0.5, CI 0.0, 5.7). There were too few outdoor housed finishing pigs to investigate this fully.

Indoors, there was an increased risk of abnormal gait in finishing pigs housed on solid concrete floors with sparse bedding, partly slatted and fully slatted floors, compared with pigs housed on solid concrete floors with deep bedding. Having controlled for age, floor type and stocking density there was a significantly higher risk of abnormal gait with increasing callus, bursa and capped hock score, compared with unaffected pigs. The risk of abnormal gait did not differ between 18 and 22 week old pigs. There was an increased risk of abnormal gait associated with the most loosely stocked 20% of pigs, (median 1.8m^2 / pig) compared to the most tightly stocked 20% of pigs (median 0.5m^2 / pig) (Table 8.7).

8.3.3.2 Gilts

In contrast to the results for finisher pigs, there was no significant difference in the risk of abnormal gait in gilts by indoor floor type or outdoor housing, compared with solid concrete floors with deep bedding. There was no difference in risk between pregnant and maiden gilts. Due to the low numbers of score three capped hock and bursitis, score two and three were combined for analysis. Having controlled for pregnancy status and floor type, there was a significantly increased risk of abnormal gait associated with increasing callus score. There was an increased risk of abnormal gait associated with capped hock score two and three compared with gilts unaffected with capped hock. However, in contrast to the results for finishing pigs, there was no association between the prevalence of bursitis and abnormal gait (Table 8.7).

8.3.3.3 Pregnant sows

There was no significant difference in the prevalence of lameness between outdoor housed sows and sows housed indoors (OR 0.8, CI 0.3, 1.9). However, there was a significantly increased risk of abnormal gait in sows housed on slatted floors compared with sows housed outdoors (OR 4.8, CI 1.3, 17.5). Within indoor housed sows there was an increased risk of abnormal gait in sows housed on slatted floors compared with sows housed on solid concrete floors with deep bedding in all areas. Having controlled for floor type, there was a trend for increased risk of abnormal gait associated with increasing score of callus, bursa and capped hock compared with unaffected pigs; however the majority of these confidence intervals included unity (Table 8.7).

Table 8.7: Two level logistic binomial models of the risks associated with abnormal gait in indoor finishing pigs, gilts and pregnant sows

	Finishing pigs n = 1409		Gilts n = 1387		Pregnant sows n = 784	
Intercept coefficient	-4.0		-2.5		-2.3	
	OR	CI	OR	CI	OR	CI
Age / stage						
18-week old finisher	1.0					
22-week old finisher	0.9	0.6, 1.3				
Maiden gilts			1.0			
Pregnant gilts			1.2	0.8, 1.7		
Floor type						
Solid deep bedding all areas	1.0		1.0		1.0	
Solid deep / sparse bedding all areas	1.8	0.6, 5.5	0.6	0.3, 1.2	1.5	0.6, 3.5
Solid sparse bedding all areas	4.4	1.5, 13.3	0.9	0.4, 2.0	1.4	0.5, 4.4
Solid deep bedding in lying area	-	-	1.5	0.6, 3.8	0.7	0.2, 2.4
Solid sparse bedding in lying area	-	-	1.0	0.3, 3.5	0.4	0.1, 2.1
Slatted* partly	3.3	1.1, 10.2	0.9	0.3, 2.6	4.6	1.4, 15.2
fully	4.6	1.5, 14.2				
Outdoor	1.3	0.1, 16.3	1.2	0.5, 2.8	1.0	0.3, 2.9
Callus on limb						
Score 0	1.0		1.0		1.0	
Score 1	1.5	1.0, 2.4	1.6	1.0, 2.5	1.4	0.7, 2.5
Score 2	1.8	1.2, 2.7	2.6	1.5, 4.4	1.7	1.0, 3.1
Score 3	2.7	1.5, 5.0	2.9	1.2, 6.9	1.6	0.8, 3.3
Bursa on limb						
Score 0	1.0		1.0		1.0	
Score 1	1.3	0.8, 2.1	0.8	0.5, 1.2	1.1	0.6, 1.9
Score 2†	2.0	1.3, 3.1	1.1	0.7, 1.9	1.2	0.6, 2.2
Score 3	2.6	1.5, 4.4			2.8	0.8, 9.9
Capped hock on limb						
Score 0	1.0		1.0		1.0	
Score 1	1.8	1.2, 2.6	1.1	0.7, 1.6	1.0	0.6, 1.7
Score 2†	2.6	1.6, 4.2	1.8	1.02, 3.08	1.3	0.7, 2.3
Score 3	4.9	1.8, 13.0			1.9	0.5, 6.8
Average m^2/pig						
Category 1 ~ $0.5m^2$	1.0					
Category 2 ~ $0.7m^2$	1.8	0.9, 3.4				
Category 3 ~ $1.0m^2$	1.3	0.6, 2.6				
Category 4 ~ $1.2m^2$	1.5	0.7, 3.2				
Category 5 ~ $1.8m^2$	2.7	1.2, 6.0				
Random effect	Var.	SE	Var.	SE	Var.	SE
Farm	0.5	0.2	1.8	0.4	1.0	0.3
Pen	0.2	0.2				
Hosmer-Lemeshow goodness-of-fit	χ^2	P value	χ^2	P value	χ^2	P value
	9.4	0.10	20.9	$p<0.05$	12.3	$p<0.05$

*Partly and fully slatted pens are combined for gilts and sows due to small numbers
†Score two and three capped hock were combined in gilts due to small numbers

8.3.4 Logistic regression analysis of the risks associated with abnormal posture in lactating sows

The risk of abnormal posture increased when lactating sows had been housed on slatted floors during gestation compared with solid concrete floors with bedding. There was no significant association between abnormal posture and the farrowing pen floor (Table 8.8).

Table 8.8: Two level logistic binomial model of the risks associated with abnormal posture in 232 indoor housed lactating sows

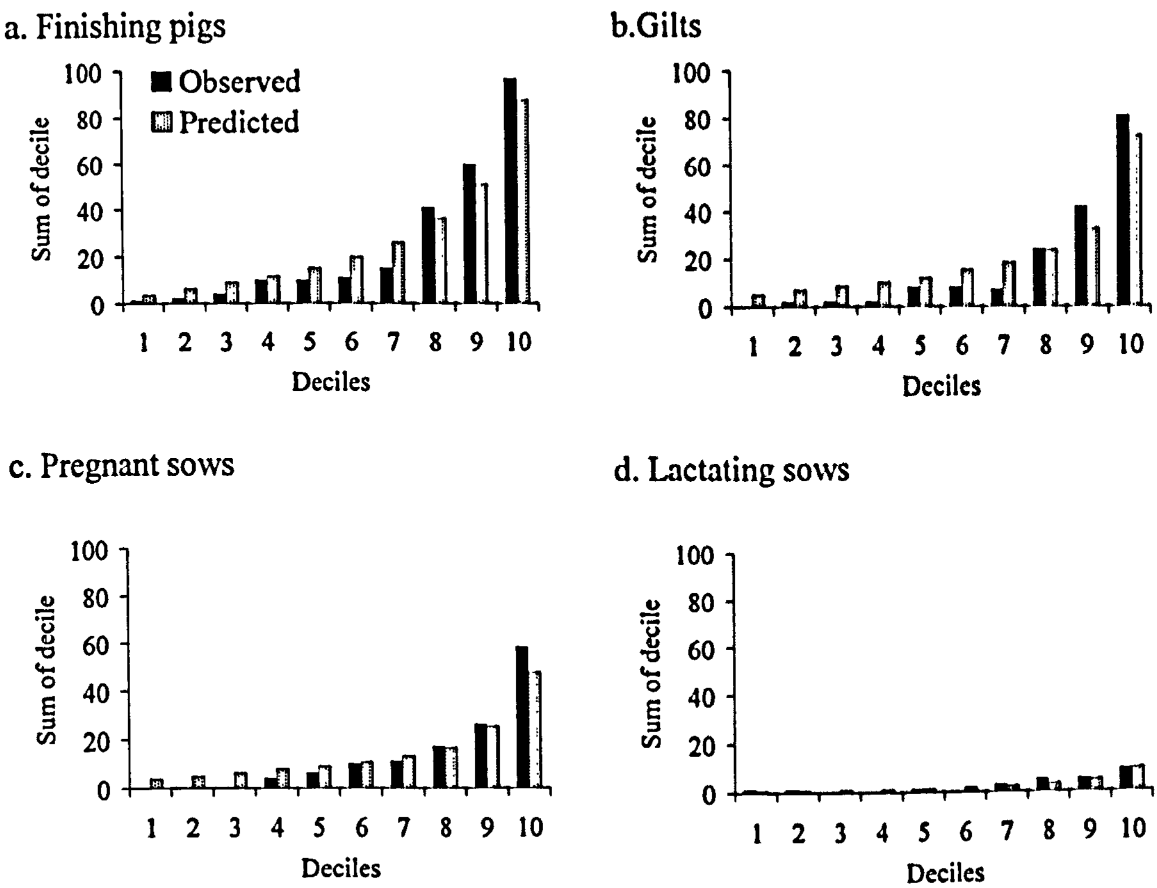
	Abnormal posture	
Intercept coefficient	-3.9	
	OR	**CI**
Week of lactation (1 – 4)	0.8	0.5, 1.3
Farrowing floor /bedding		
Solid concrete with bedding	1.0	
Part slatted / solid concrete with bedding	2.3	0.2, 29.9
Part slatted / solid concrete no bedding	0.5	0.1, 6.4
Fully slatted	2.3	0.2, 29.9
Gestation floor type		
Solid concrete with bedding	1.0	
Part / fully slatted	5.9	1.6, 22.7
Wound on limbs		
Score 0	1.0	
Score 1	3.8	0.9, 16.0
Score 2 and 3	5.0	1.4, 17.9
Callus on limbs		
Score 0 and 1	1.0	
Score 2	1.7	0.3, 10.7
Score 3	3.1	0.5, 17.3
Any-foot-lesion		
Score 0 or 1	1.0	
Score 2	3.0	0.9, 9.3
Score 3	7.0	1.4, 35.6
Random effects	**Var.**	**SE**
Farms	0.0	0.0
Hosmer-Lemeshow goodness-of-fit	χ^2	**P value**
*df = 3	1.5*	0.77

Having controlled for floor type, there was an increasing prevalence of abnormal posture in sows with score two or three wounds on the limbs compared with unaffected pigs. Having controlled for floor type and presence of limb lesions, there was an increased risk of abnormal posture associated with any-foot-lesion score two or score three compared with pigs with no foot lesions or lesion score one (it was necessary to combine score zero and one because there were no sows that had abnormal posture and did not have a foot lesion) (Table 8.8).

8.3.5 Model fit and observer differences for logistic models

The Hosmer-Lemeshow goodness-of-fit statistic indicated that the difference between the observed and predicted was larger for the gilt and pregnant sow models than for finisher pigs and lactating sows (Table 8.8). However, the graphs of expected verses observed values indicated there the predictions were a reasonable fit to the data, although there was a trend for under prediction in the higher deciles (Figure 8.1). Controlling for observer in the models did not alter the interpretation of any of the fixed effects.

Figure 8.1: Graphs a-d of observed verses predicted values from logistic binomial regression models for lameness



8.3.6 Multinomial analysis of the risks associated with abnormal gait score one or score two and above

In indoor housed finishing pigs and indoor and outdoor housed gilts and pregnant sows, the associations between abnormal posture, limb lesions and floor type in the multinomial models were similar to the patterns from the logistic models described above. However, due to the smaller number of pigs in each category the confidence intervals of many factors included unity (Appendix E).

8.4 Discussion

In the current study the prevalence of abnormal gait was higher than reported in comparable pervious studies of finishing pigs and pregnant sows (Gjein and Larssen, 1995b; Smith and Morgan, 1997; Krieter *et al.*, 2004; Heinonen *et al.*, 2006; van den Berg *et al.*, 2007). This may be an indication that the prevalence of lameness in commercial English pig farms is higher than previously reported and higher than in other European countries. However, differences between studies might also be due to differences in the classification of a lame pig. The ordinal scoring system devised by Main *et al.* (2000), used in the current study, has the advantage that each level of abnormal gait had a clear case definition.

In the current study a low cut-off to define lameness was selected, pigs whose stride length was abnormal and movements were no longer fluid, were classified as lame. In contrast, Kriter *et al.* (2004) and Smith and Morgan (1997) both specified that pigs with a stiff gait or abnormal posture were defined as sound. If the cut-off of an affected pig in the current study was increased to score two (shortened stride, lameness detected), the prevalence of affected pigs would reduce to 6.4%, 3.3%, 6.5% for finisher pigs, gilts and pregnant sows respectively. If the criteria for classification of abnormal gait was increased still further to score three (minimal weight bearing on affected limb), the prevalence of affected finisher pigs, gilts and pregnant sows respectively would reduce to 1.4%, 1% and 1.8%. These latter values are similar to the low figures reported by Krieter *et al.* (2004) in finishing pigs in Switzerland. It is essential to be clear on the definition of an affected animal before studies can be meaningfully compared and some studies fail to specify the case definition used (Gjein and Larrsen, 1995b; van den Berg *et al.*, 2007).

In the current study it was not practical to let lactating sows out of the farrowing crate to assess their gait, therefore posture was used as a measure of soundness for lactating sows. Gait and posture were highly correlated in finishing pigs, gilts and pregnant sows. However, 60% of pregnant sows with abnormal gait had normal posture, suggesting that gait was a more sensitive measure of lameness than posture. Assuming a similar association in lactating sows, it is probable that the prevalence of unsound lactating sows was underestimated in the current study as a result of using posture as the outcome and if gait had been observed a higher proportion of pigs would have been classified as lame.

As reported in previous studies (Jørgensen, 2003; Heinonen *et al.*, 2006; Scott *et al.*, 2006) slatted unbedded floors were associated with an increased risk of abnormal locomotion in finishing pigs and pregnant sows and abnormal posture in lactating sows. This is an important result as lameness caused by pain and discomfort is a clear indication of reduced welfare. It might be that no association between abnormal gait and floor type was detected in gilts because they are likely to have been recently moved into the current accommodation.

It is useful to examine gilts to know the prevalence of disease in pigs as they enter the breeding herd. However, the results from the current study have indicated that gilts are not a suitable group in which to investigate environmental risk factors in a cross-sectional study. Gilts are commonly bought in, and as the future of the breeding herd, are often housed on more 'comfortable' than average floors. As such the prevalence of disease associated with flooring is likely to be low, but what disease is present might not be associated with the floor they are housed on at the time of observation.

In previous work, a higher prevalence of culling for lameness in outdoor housed sows compared with indoor sows was reported (Cox and Bilkei, 2004). There were no indications in the current study that outdoor housing was associated with an increased prevalence of lameness. Conversely, in finishing pigs and pregnant sows the prevalence of abnormal gait was lower outdoors than in pigs housed on slatted floors and none of the outdoor housed lactating sows had abnormal posture, compared with a prevalence of 11% in lactating sows housed indoors. However, only 30 lactating sows were examined outdoors and the circumstance under which the data was collected was very different from indoor housing where sows can be closely examined. To better understand the impact of indoor verses outdoor housing on the prevalence of lameness it would be useful to be able to examine pigs housed in both environments, including a larger sample of outdoor housed pigs, under the same conditions, i.e., walking and standing on a level uniform surface.

There was a general trend for an increase in the risk of abnormal locomotion with increasing callus, bursa and capped hock score in finishing pigs and an increased risk of abnormal posture associated with wounds on the limbs in lactating sows. Similar results in sows have been reported by Bonde *et al.* (2004) and von Berner et al., (1990). It is possible that the limb lesions affected the pig's locomotion.

There are some indications that bursitis and capped hock may be associated with discomfort as they develop (von Berner *et al.*, 1990). But it seems unlikely once this stage has passed that they would cause sufficient discomfort or stiffness to affect a pig's gait. Certainly this appears to be an implausible explanation of the association between calluses and abnormal locomotion, as calluses are unlikely to be painful.

An alternative hypothesis is that limb lesions are correlated with foot lesions, as reported in finishing pigs by Mouttotou *et al.* (1998) and that foot lesions are causing the abnormal gait or posture (Dewey *et al.*, 1993; Gjein and Larssen, 1995b; Kirk *et al.*, 2005; Anil *et al.*, 2007). In the current study, feet, limbs and lameness were only examined in the same animals in lactating sows housed indoors. In these pigs abnormal posture was associated with foot lesions and the risk increased with the severity of the lesion. This suggests that foot lesions are causing the sow sufficient discomfort to affect their posture. It might be that a similar association was occurring in finishing pigs, gilts and pregnant sows in this study. This hypothesis also appears to makes sense given that the prevalence of foot lesions (Chapter 7), along with lameness, were comparable in indoor and outdoor housed pigs, while limb lesions were significantly less prevalent in outdoor housed pigs of all ages (Chapters 3, 4, 5 and 7). However, it is not known whether associations that occurred in lactating sows can be generalised to pigs of different ages and in different housing.

It is plausible that limb lesions and lameness are also associated because lame pigs spend more time lying down, because they are uncomfortable standing or walking. Lame pigs also have more difficulty making the transition between standing and lying (Bonde *et al.*, 2003) which might increase the risk of lesions developing on the limbs. This would explain why accounting for floor type does not fully explain the increasing risk of abnormal gait or posture and why there is additional risk associated with increasing limb lesion score.

Bursitis and capped hock were not as strongly associated with abnormal gait in gilts and sows as in finishing pigs. As discussed in Chapter 4, this might have occurred because these lesions were chronic. Therefore, the capped hock and bursitis observed in these gilts and sows may not be associated with the current flooring or locomotion of the pig. Wounds and calluses on the limbs are likely to resolve with time which may explain why wounds were significantly associated with the current floor type in lactating sows and there was a similar association between abnormal gait and calluses in gilts.

Stocking density was correlated with floor type in pigs of all ages (Chapter 2 Table 2.23, Table 2.25). In finishing pigs, having controlled for floor type and prevalence of limb lesions, there was an increased risk of abnormal gait in the most loosely stocked pigs. It is possible that low stocking density is associated with lameness because loosely stocked pigs are more active and therefore have greater opportunity to injure themselves. However, this association might have occurred in the current study because it was easier to detect abnormal gait in the most loosely stocked pens. It is also possible that pens with very low stocking density in pigs close to slaughter age occurred because some of the pigs had already gone to slaughter and lame pigs were left behind thereby increasing the prevalence of lameness in the pen. As reported in previous studies (Gjein and Larssen, 1995b; Heinonen *et al.*, 2006) stocking density was not significantly associated with abnormal posture in gilts and sows and did not impact on the interpretation of other fixed effects so it was not included in the models. This may have occurred because breeding pigs are typically stocked at lower densities than finisher pigs.

A limitation of examining pigs for lameness in a cross-sectional study is that pigs were examined walking on different surfaces. It is possible that a pig may appear to have an abnormal gait if it is having difficulty navigating a slatted or slippery surface but may have normal locomotion on a surface that is easier to walk on (Phillips and Morris, 2000). Other reasons gait may be altered without the animal experiencing pain or discomfort include joint stiffness or poor conformation (Weary *et al.*, 2006). Because of the low cut-off used to define lameness in the current study (abnormal stride length and movement no longer fluid) it is less clear that what we measured as abnormal gait is an indication of pain and discomfort. However, the results from the multinomial models indicating that unmistakably lame pigs (score two or above) were associated with floor type in a broadly similar manner as pigs in the mild category might be an indication that these classifications represent a continuum of the same outcome. Additionally, the fact that there was an increased risk of abnormal posture in lactating sows associated with the floor in their accommodation when pregnant suggests that slatted floors were associated with sustained damage rather than simply altering posture. Finally, gilts on slatted floors did not have an increased risk of abnormal locomotion which suggests that 'normal' locomotion on slatted floors was not always being misclassified as lameness.

8.4.1 Conclusions

In the current study lameness was measured in finishing pigs, gilts and sows. The prevalence of lameness was high in comparison with previous studies, probably because mildly affected pigs were defined as lame. There were no differences in the prevalence of abnormal locomotion between pigs housed outdoors and pigs housed indoors on solid concrete floors with bedding. However, there was increased prevalence of abnormal locomotion associated with pigs housed on slatted floors, possibly due to an increased prevalence of painful foot lesions in pigs on these floor types (Chapter 7). There was a significant association between abnormal gait or posture and limb lesions and in lactating sows, foot lesions, possibly because both outcomes were associated with slatted floors and because lame pigs might spend more time lying thus increasing the risk of limb lesions.

Chapter 9

General discussion and future work

9.1 Introduction

The current study provides the most accurate estimates for the prevalence of foot, limb and body lesions and lameness in the English pig herd to date. In addition, the sample of farms, which we believe are representative of the population, provided a snap shot of the floor types that pigs were housed on and the likely impact of these floors on the prevalence of lesions and lameness in pigs.

This thesis builds on a previous thesis on foot and limb lesions in pigs by Mouttotou (1998), subsequently published as Mouttotou *et al.* (1997; 1998; 1999a; 1999b; 1999c; 1999d) and Mouttotou and Green (1999). The case definitions devised by Mouttotou (1998) were modified for use in the current study to ensure the range and severity of lesions was captured and lesion score accounted for the size of pig examined. The external validity of Mouttotou's prevalence estimates were improved because a larger more representative sample of farms was used in this study. The research was also extended by including adult pigs in the investigation and by measuring the prevalence of lameness.

In most areas this study had sufficient power to identify important significant associations and on occasion, non significant results, for example the lack of a significant difference between the prevalence of lameness in sows housed indoors on solid floors with deep bedding and sows housed outdoors on soil, were of equal importance. However, despite the large number of farms visited, there were areas where there was insufficient data to draw conclusions, for example the small number of finishing pigs housed outdoors limited the power to detect a significant difference between indoor and outdoor housing on the prevalence of lameness. Such areas could be investigated further in a non random sample of farms, however, given the small proportion of the national herd in England that might be exposed to such factors, (based on the assumption that these farms are representative) it might not be considered a priority. I conclude that any future studies on the prevalence of foot and limb lesions and lameness in pigs in Britain must surpass the size and representativeness of the current study and improve on the accuracy and detail of data collected to add usefully to our knowledge.

9.2 Research findings and implications

This is the first study where the prevalence of foot, limb and body lesions and lameness has been investigated in outdoor housed pigs. In all ages of outdoor housed pigs there was a lower prevalence of limb lesions compared with pigs housed indoors. In lactating sows there was also a lower prevalence of body lesions in pigs housed outdoors compared with indoors (Chapters 3, 4, 5 and 6). It is likely that these differences occurred because soil provides a solid, but yielding surface and the lying areas within the huts were deeply bedded. The lower stocking density outdoors and lack of confinement for lactating sows, might also have contributed to the lower prevalence of injuries observed.

It might be assumed that the prevalence of foot lesions in outdoor housed pigs would also be low, as soil is the substrate for which pigs' feet have evolved.

However, this was the case for piglets, but not for gilts and sows (Chapters 6 and 7). The low prevalence of foot lesions in piglets might have occurred because of the deep straw bedding in the farrowing huts, where young piglets spend the majority of their time when their feet are most soft and vulnerable (Johnson et al., 2001). It was clear that slatted and abrasive indoor floors damaged piglets' feet. Post-mortem examination of these lesions indicated that even when the visible external lesions were apparently mild, infection could be present in the hoof, which was likely to be a painful chronic injury for affected piglets.

In contrast to piglets, the prevalence of foot lesions in outdoors housed gilts and sows (57%) was almost as high as in those housed indoors (68%) (Chapter7). It might be that although pigs' feet are well suited for soil, paddocks in commercial outdoor production were very different from the woodland habitat for which pigs feet have evolved. Wet conditions might soften the hoof and damage might occur from standing on rocks.

The prevalence of lameness was also similar between outdoor housed pigs and those housed indoors on solid floors; but was higher in pigs housed on slatted floors (Chapter 8). This might be associated with the prevalence of foot lesions in these groups of pigs. This hypothesis is supported by the positive association between the prevalence of lameness, foot lesions and slatted floors in lactating sows (Chapter 8). However, it must be noted that slatted floors were only associated with an increased prevalence of certain foot lesions. It might be that foot lesions that develop on slatted floors are more painful than those that develop on soft wet floors, or that it is more painful walking with foot lesions on hard and slatted surfaces. The results from the post-mortem examination of these foot lesions did suggest that heel flaps, which are associated with slatted floors, developed as a result of haemorrhage within the sole and are therefore likely to be associated with discomfort (Appendix D). However, the pathology associated with toe erosions, which commonly occur on solid floors with bedding, is unknown. A further investigation into the association between the prevalence of foot lesions and lameness in all types and ages of pigs housed indoors and outdoors is needed. Better understanding of the different pathologies observed in the feet and discomfort they are likely to cause would also be useful.

Limb lesions were also associated with the prevalence of lameness in the current study (Chapter 8). It is probable this association occurred because lame pigs spent more time lying, thus placing more pressure and wear on their limbs, rather than the limb lesions led to poorer gait or posture. Pigs that were unwilling to rise to their feet and sows in crates small for their size were also more likely to have limb and body lesions.

The prevalence of limb lesions in indoor housed pigs was associated with the floor type. There is now little doubt that bursitis, capped hock and calluses on the limbs of post weaning pigs are associated with trauma from hard and slatted floors (Chapter 4; Smith, 1993; Mouttotou et al., 1998; 1999; Guy et al., 2002; Cagienard et al., 2005; Scott et al., 2006). The current study was the first to examine the risks associated with these lesions in gilts and sows. In lactating sows housed in farrowing crates, the associated risks by floor type were similar to those for post weaning pigs (Chapter 5).

However, in gilts and pregnant sows (Chapter 4), the prevalence of limb lesions did not vary with the presence of slats or quantity of bedding in the same way as for post weaning pigs. This might have occurred because in older pigs some limb lesions are chronic and developed when the pig was previously housed on a different floor type. There might also have been a lack of detectable association because of the lack of variation in floor type; most gilts and pregnant sow were housed on solid floors with straw bedding.

9.2.1 Impact of flooring on the welfare of the pig

It is clear from the data presented that flooring can affect the welfare of the pig; that is, according to the definition of welfare of Webster (2001), affect the pig's fitness and happiness. Gait or posture alterations, resulting from pain or discomfort, are an obvious indication that the pig's welfare is compromised. The reduced fitness of lame pigs also has an impact on productivity owing to cost of treatment (Christensen *et al.*, 1994), reduced daily weight gain (DWG) (Jensen *et al.*, 2007) and premature culling (Boyle *et al* 1998; Lucia *et al.*, 2000; Anil *et al.*, 2005; Engblom *et al.*, 2007).

Damage to the epidermis, as reported in lactating sows and piglets (Chapter 5 and 6), is a painful injury (Bateson, 1992) and therefore the welfare of the pig is compromised. However, a causal relationship between these lesions and reduced productivity has not been illustrated (though see for discussion: Phillips and Pawluczuk, 1995; Philips et al., 1995: Mouttotou and Green, 1999; Johansen et al., 2004; Norring et al., 2006). But behavioural differences in piglets with injuries have indicated the welfare cost associated with these lesions. Mouttotou and Green (1999) reported that piglets with foot and limb lesions were less active, and spent less time in play activity compared with unaffected pigs.

Lesions where the epidermis is broken may be an indication that the pig is not able to cope with its environment, as they have not been able to avoid these painful lesions developing. Preweaning piglets are probably unable to cope with hard indoor floors because their epidermis is particularly soft and fragile at birth and because there is competition for food. Access to the most productive teats is so important to the fitness of the piglet, that it will outweigh the benefits of behaviour that could minimise injuries, for example attempting to avoid kneeling on abraded carpals. In lactating sows, although it appears likely that wounds on the limbs and body result from contact with the floor, confinement in the farrowing crate and enforced immobility, may be a key feature that restricts the sow's ability to cope with the environment, e.g. wounds develop rather than calluses.

It is desirable that pigs are not harmed in any way by the floor they are housed on; however some degree of adaptation might be deemed to be acceptable. Bursal swellings and calluses are an indication that the environment the pig is housed in is less than ideal. However, because the there is nothing restricting the swelling on the limbs where bursae develop, they are not likely to be particularly painful, as least after the initial trauma (P. Ossent personal communication). Indeed calluses and bursal swellings may reduce discomfort associated with lying on a hard surface. As such these lesions might be an indication that the pig is adapting to and therefore coping in, its, less than ideal, environment.

9.2.2 Implications of the research findings with reference to pig production outside Britain

Housing systems for pigs have changed significantly over the last 50 years as the intensification of pig production has favoured slatted and unbedded floors. Overall, the results from this study indicate that these types of floor are associated with increased prevalence of limb and body lesions and lameness in pigs compared with more traditional housing of pigs on soil or solid floors with bedding. These results will help legislative bodies to understand the impact of flooring on the health and welfare of pigs in Britain, particularly with regard to forthcoming EC directives (Commission directive, 2001; Council directive, 2001).

There is little comparable data on the floor type pigs are housed on in other countries. Based on expert opinion Hendriks et al. (1998) estimated that 83% of gestating sows, 86% of lactating sows and piglets, 92% of weaners and 91% of grower and finishers across Europe are housed on slatted floors. The results from the current study indicate that the prevalence of unbedded and slatted systems is considerably lower in Britain than the European average (Chapter 2). If the association between floor type and the prevalence of foot, limb and body lesions and lameness in other European countries is similar to Britain, then it is probable the prevalence and severity of lesions and lameness in these countries is higher than reported in the current study. Based on these assumptions, it is surprising that, with the exception of Switzerland (Krieter et al., 2004; Cagienard et al., 2005), there is so little research into injuries in pigs caused by the floor in other pig producing countries. However, research funding is limited. Allocation of resources is political and focused on problems that affect the cost of production and welfare issues that attract the interest of lobby groups.

9.3 Limitations of the research and suggestions for further work

In the current cross-sectional study a snap-shot of the data were taken, this provided a good estimate of prevalence and has proved useful to generate hypotheses regarding the causality of lesions. For outcomes where the exposure was very strongly associated with the prevalence, such as the increased risk of limb lesions in indoor housed pigs compared with outdoor housed pigs, population attributable fractions were calculated. However, in some cases, for example the association reported between limb lesions and lameness, it is not clear which is cause and which is effect. To understand the aetiology of foot, limb and body lesions and lameness in pigs, longitudinal studies to establish temporality are required. This approach is particularly necessary for older pigs, which have potentially been exposed to many floor types and environments, the impact of which cannot be elucidated in a cross sectional study.

The farmers invited to take part in the study were randomly selected from the Assured British Pig database. However, the study farms are not a true random sample as there was self-selection among those invited to take part and compliance was low. Responses from farmers stating the reasons why they chose not to participate in the current study should be addressed in further work; too arduous a study, insufficient financial compensation and biosecurity fears were commonly stated. Overall the pig industry in Britain is under extreme economic pressure and is in decline so farmers have minimal resources to accommodate research on their farms. In the current study because data collection was combined with the PMWS study, approximately 5 – 8 hours of the farmer's time was required. Even though monetary compensation was offered (£100), for some this would be inadequate to cover their costs and some would not have sufficient staffing to accommodate the extra work. Future studies must be designed with the minimal inconvenience to the farmer to maximise participation.

Another factor of the large work load associated with combining the two projects was that a large team of field workers was needed to collect the data. The original research proposal for the current study was for two research assistants to collect all the data, thus minimising interobserver variability. Instead eight observers collected data in the current study and it is likely there was variability between observers. A limitation of this thesis is that a study of the inter-observer and intra-observer variability was not carried due to the practical difficulties. Problems included; access to pigs where the farmer was willing for a large group of people to come on to the farm and handle the pigs (Warwick University does not have access to a teaching unit), time limitations, and because not all staff were employed on the project at the same time. This validation is essential for future studies, but these are not easy data to collect, because pigs become stressed by repeated handling. Use of photos or samples from slaughtered pigs for lesions, or videos for gait score, could be used to assist this process.

The inter-observer variability of the lameness scoring system utilised in the current study was reported by Main et al. (2000) to be acceptable in trained observers. However, further work is required to determine whether the lameness scores are measuring pain experienced by the pig. In cows this has been done by injecting animals classified as lame and sound with local anaesthetic in the affected foot, or the matched foot for controls, and measuring alterations in gait (Rushen et al., 2007). It is possible that a similar procedure could be used with sows providing lameness could be diagnosed and treatments administered successfully. Pigs tend to be more difficult to handle than cows. Other reasons gait may be altered without the pig experiencing pain include; joint stiffness, poor confirmation or difficulty navigating the surface (Phillips and Morris, 2000; Weary et al., 2006). However, even if these alterations in gait are not painful, they indicate impairment of normal physical function and as such might subsequently be associated with an increased risk of painful lameness.

The data in the current study had a hierarchical structure, pigs were clustered within pens and pens were clustered within farms. Multilevel models were used to account for this structure, with the addition of random effects at the level of the farm and the pen. This technique minimises the underestimation of the standard errors that occurs when the data points are not independent and thus reduces the risk of type I errors (Rasbash et al., 2004). However, the model diagnostics available for logistic and multinomial multilevel models are currently limited and Hosmer-Lemeshow goodness-of-fit test is at this time one of the few methods available. The Hosmer-Lemeshow statistic is calculated from the categorised then summed observed and predicted values. The predicted values, which are the probably that the pig is affected, may be small, but are never zero. Consequently, models appear to fit poorly for low values when there are large numbers of data points in each category, because the sum of the predictions is greater than the sum of the observed values, which if the pigs is unaffected are true zeros. Overall, logistic regression models with a binary outcome appeared to fit less well than models where the outcome was a proportion. Cross-validation or leave-one-out approach could be used to determine the how well the model predicted the remaining data points based on a proportion of the data (Dohoo et al., 2003). However, this method is computationally and time demanding and beyond the scope of this thesis.

9.4 Conclusions

This study provides, to date, the most accurate estimates for the prevalence of foot, limb and body lesions and lameness in the English pig herd. Data have also been presented on the floor types that pigs were housed on and the likely impact of these floors on the prevalence of lesions and lameness in pigs. These results will inform legislative bodies on the likely impact of flooring on the health and welfare of pigs in Britain, particularly with regard to forthcoming EC directives (Commission directive, 2001; Council directive, 2001). Results from the current research and other published evidence, should now be used to design cohort and / or intervention studies to test the hypotheses generated.

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Appendix C

Sow observation sheet

Initials		**Date**							
Farm I.D.		Building I.D.		Room I.D.		Pen I.D		Sow I.D	

Litter information						**Age group (circle)**
No. of piglets in pen		Parity of sow		Age of piglets (days/DOB)		3-7d
						8-14d
No piglets born alive		No. piglets born dead		No. piglets died since birth		15-21d
						22-28d

Initial response of sow to human approach (circle one)			
Bright alert and responsive (pig rises immediately and approaches inquisitively)	**Bright but less responsive** (may remain down, or dog sitting, before eventually rising)	**May be dull** (only rises when strongly motivated)	**Dull and unresponsive**

Sow observations

Sow body sores (1-3)							**Sow skin damage (score 1-3)**				
None	Shoulder		Hip		Tail	Top of back	**None**	Head/ neck	Shoulders	Trunk	Hind quarters
	L	**R**	**L**	**R**							
New											
Old											

Sow limb lesions (1-3)									**Other limb injuries**
Front limbs				**Hind limbs**					
None	Bursa	Calluses	Skin wound	None	Bursa	Capped hock	Calluses	Skin wounds	
R				**R**					
L				**L**					

Size of sow in crate - Sow standing forward with nose in trough (circle)				**Body condition score** (1-5)	**Cleanliness - % of skin** covered with dirt
Between back and top of crate	>10cm	10-5cm	<5 cm		None
					<25%
Between tail and back of crate	>20cm	20-10cm	<10 cm		25-50%
					>50%

Standing posture (circle one)				
Pig stands squarely on all four legs	Uneven posture	Uneven posture. Will not bear weight on affected limb (appears to be standing on toes)	Affected limb elevated off floor. Pig appears visibly distressed	Will not stand unaided

Foot lesions (back left) score 1-3													
None	Hoof wall lesions					Volar lesions							
	Wall crack	Wall bruise	Wall pen.	Over grown	Uneq. claw size	Toe ero.	Heel ero.	Sole ero.	Heel flap	Heel corr.	White line crack	White line sep.	Other

Appendix E

Table 1: Three level multinomial model of the risks associated with abnormal posture score one and score two or above in 1380 indoor finisher pigs

	Score 1		Score 2+	
Intercept coefficient	-4.2		-4.2	
	OR	**CI**	**OR**	**CI**
Age				
18-week	1.0			
22-week	1.0	0.9, 1.1	0.9	0.8, 1.1
Floor type				
Solid deep bedding all areas	1.0			
Solid deep / sparse bedding all areas	1.9	0.6, 5.9	1.5	0.1, 16.4
Solid sparse bedding all areas	3.0	0.9, 9.7	11.1	1.3, 98.3
Partly slatted partly solid	3.0	0.9, 9.7	6.8	0.7, 63.8
Fully slatted	3.0	0.9, 9.8	15.3	1.7, 141.3
Callus on limb				
Score 0	1.0			
Score 1	1.8	1.1,2.9	1.0	0.4, 2.1
Score 2	1.7	1.1, 2.8	2.0	1.0, 3.8
Score 3	2.4	1.2, 4.7	3.5	1.5, 8.4
Bursa on limb				
Score 0	1.0			
Score 1	1.6	0.9, 2.7	0.7	0.3, 1.7
Score 2	2.1	1.3, 3.4	1.4	0.7, 2.8
Score 3	2.9	1.6, 5.2	1.6	0.7, 3.4
Capped hock on limb				
Score 0	1.0			
Score 1	2.2	1.5, 3.4	1.0	0.5, 1.9
Score 2	2.9	1.7, 5.0	2.2	1.1, 4.6
Score 3	4.2	1.4, 12.7	7.6	2.2, 26.2
Average m^2/pig				
Category 1 ~ $0.5m^2$	1.0			
Category 2 ~ $0.7m^2$	1.4	0.7, 2.7	2.5	0.9, 6.7
Category 3 ~ $1.0m^2$	1.1	0.5, 2.4	1.7	0.5, 5.2
Category 4 ~ $1.2m^2$	1.5	0.7, 3.2	2.1	0.6, 7.2
Category 5 ~ $1.8m^2$	2.2	1.0, 5.0	4.3	1.1, 16.1
Random effects	**Var.**	**SE**	**Var.**	**SE**
Variation at farm level	0.7	0.2	1.1	0.5
Variation at pen level	0.0	0.0	0.4	0.4
Covariance between scores				
Farms	0.2	0.2		
Pens	0.0	0.0		

Table 2: Three level multinomial model of the risks associated with abnormal posture score one and score two or above in 1387 maiden and pregnant gilts

	Score one		Score two+	
Intercept coefficient	-0.3		-4.1	
	OR	**CI**	**OR**	**CI**
Pregnancy status				
Maiden gilt	1.0		1.0	
Pregnant gilt	1.2	0.7, 2.1	1.2	0.6, 2.4
Floor type				
Solid deep bedding all areas	1.0		1.0	
Solid deep / sparse bedding all areas	0.9	0.2, 3.5	0.6	0.2, 1.6
Solid sparse bedding all areas	1.4	0.5, 4.0	1.2	0.5, 3.1
Solid deep bedding in lying area	1.1	0.5, 2.7	0.2	0.0, 2.1
Solid sparse bedding in lying area	0.7	0.3, 1.7	0.3	0.0, 2.8
Slatted	1.3	0.4, 4.7	0.7	0.2, 2.7
Outdoor	1.8	0.7, 4.6	1.5	0.5, 4.6
Callus on limb				
Score 0	1.0		1.0	
Score 1	2.0	1.2, 3.3	1.2	0.5, 3.1
Score 2	2.7	1.5, 5.0	3.0	1.2, 7.4
Score 3	2.2	0.7, 6.3	6.5	2.0, 20.9
Bursa on limb				
Score 0	1.0		1.0	
Score 1	0.9	0.6, 1.6	0.6	0.2, 1.7
Score 2 and 3	0.9	0.3, 2.1	2.3	1.0, 5.1
Capped hock on limb				
Score 0	1.0		1.0	
Score 1	1.1	0.7, 1.8	1.0	0.5, 2.2
Score 2 and 3	1.9	1.0, 3.5	2.0	0.8, 5.1
Random effects	**Var.**	**SE**	**Var.**	**SE**
Variation at farm level	1.8	0.4	0.5	0.5
Variation at pen level	0.0	0.0	0.0	0.0
Covariance between scores				
Farms	0.5	0.3		
Pens	0.0	0.0		

Table 3: Three level multinomial model of the risks associated with abnormal posture score one and score two or above in 776 pregnant sows

	Score one		Score two+	
Intercept coefficient	-3.0		-2.8	
	OR	**CI**	**OR**	**CI**
Floor type				
Solid deep bedding all areas	1.0		1.0	
Solid deep / sparse bedding all areas	0.5	0.1, 2.9	0.3	0.0, 3.5
Solid sparse bedding all areas	0.6	0.1, 2.5	0.7	0.2, 3.2
Solid deep bedding in lying area	1.1	0.3, 3.8	2.0	0.6, 6.8
Solid sparse bedding in lying area	1.6	0.6, 3.9	1.2	0.4, 3.4
Slatted	3.6	1.1, 12.2	6.3	1.8, 22.0
Outdoor	1.2	0.4, 4.1	0.7	0.2, 2.9
Callus on limb				
Score 0	1.0		1.0	
Score 1	1.5	0.7, 3.1	1.2	0.5, 2.7
Score 2	2.5	1.3, 4.9	0.9	0.4, 2.0
Score 3	1.7	0.7, 4.1	1.5	0.6, 3.8
Bursa on limb				
Score 0	1.0		1.0	
Score 1	1.3	0.7, 2.5	0.8	0.4, 1.8
Score 2	1.7	0.9, 3.3	1.0	0.4, 2.2
Score 3				
Capped hock on limb				
Score 0	1.0		1.0	
Score 1	0.9	0.5, 1.7	1.1	0.6, 2.2
Score 2	1.6	0.9, 3.0	1.1	0.5, 2.5
Score 3				
Random effects	**Var.**	**SE**	**Var.**	**SE**
Variation at farm level	0.7	0.3	0.5	0.4
Covariance between scores				
Farms	1.0	0.3		

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