A cross-sectional study on the prevalence and risk factors for foot and limb lesions in piglets on commercial farms in Ireland

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Abstract

A cross-sectional survey of 68 integrated Irish pig farms was conducted to determine the prevalence and risk factors for foot and limb lesions in 2948 piglets from 272 litters. One litter was selected per age category; 3–7 days, 8–14 days, 15–21 days and 22–28 days per farm. All piglets were examined for sole bruising, sole erosion, coronary band injuries, limb abrasions, alopecia, swollen limbs and swollen feet and scored from 0 to 3 based on relative size. Environmental parameters were recorded for each litter examined. A questionnaire was completed on management, health and performance factors for each farm. The overall prevalence of each lesion was calculated and multilevel mixed effect logistic regression models were used to elucidate risk factors. The prevalence (farm range) of lesions were: sole bruising = 61.5% (7–100%), sole erosion = 34.1% (0–100%), coronary band injuries = 11.3% (0–46%), limb abrasions = 55.7% (11–98%), alopecia = 24.8% (0–83%), swollen limbs = 2.4% (0–11%) and swollen feet = 4.4% (0–14%). Age was negatively associated with sole bruising (OR 0.42; CI 0.37, 0.50) and coronary band injury (OR 0.69; CI 0.60, 0.81) and positively associated with limb abrasions (OR 1.54; CI 1.12, 2.14). There was a reduced risk of sole bruising in piglets in pens with plastic slats with oval voids in the piglet area of the pen with a plastic solid area for piglets and metal slats under the crate (OR 0.32; CI 0.15, 0.70) compared with plastic stats throughout and a plastic solid area for piglets. There was an increased risk of sole erosion (OR 1.81; CI 1.07, 3.09) and foot and limb swellings (OR 1.90; CI 1.01, 3.57) in pigs in pens with metal slats only and a solid plastic area for piglets compared with plastic stats throughout and a solid plastic area for piglets. There was an increased risk of coronary band injury in pens with metal slats throughout and a metal solid area for piglets (OR 4.25; CI 1.96, 3.57) compared with plastic stats throughout and a plastic solid area for piglets. We conclude no single floor type was ideal for piglet foot and limb health with all floors influencing different lesions in different ways, however, the positive association between sole erosions, coronary band injury and foot and limb swellings and metal slats suggest that this floor type was most detrimental and most likely to be associated with joint infections that lead to severe health and welfare concerns.

Keywords: Piglet, limb lesion, foot lesion, risk factors, welfare, prevalence, mixed effect model

1. Introduction

Nursing piglets can develop various injuries to their limbs and feet (KilBride et al., 2009). Prevalence and severity vary by lesion type and environment (Mouttotou et al., 1999 and KilBride et al., 2009). However foot and limb injuries impair welfare, reduce performance and may cause death, with joint ill or lameness reported as the cause of 2.8% of preweaning mortality (Mouttotou and Green, 1999, Johansen et al., 2004, KilBride et al., 2012 and Westin et al., 2014).

Limbs are affected by skin abrasions, alopecia and swellings. Abrasions are removal of the epidermis with either an open wound or healing scab present (Mouttotou et al., 1999 and KilBride et al., 2009). They predominantly affect the carpal joint bilaterally and are caused by friction between limb and floor during feeding (Lewis et al., 2005). Abrasions develop within hours of birth and their incidence typically reduces with age (Straw et al., 2006, KilBride et al., 2009 and Zoric et al., 2009). Alopecia can arise from mild abrasions to the skin or from scar tissue which is non-hairy and typically reflects healed abrasions (Mouttotou et al., 1999 and KilBride et al., 2009).

Lesions to the foot include sole bruising and sole erosion, coronary band injuries and swellings. Sole bruising is haemorrhaging into the solar corium (Mouttotou and Green, 1999 and KilBride et al., 2009). It is most prevalent in the first week of life when the epidermis is very thin (Zoric et al., 2008 and KilBride et al., 2009). Erosion arises when the sole epidermis is removed (Mouttotou and Green, 1999 and KilBride et al., 2009). Both lesions are associated with a reduction in suckling and active behaviour and a slower growth rate; probably because of the pain associated with such injuries (Mouttotou and Green, 1999). Little is known about coronary band injuries but it is thought to arise when the toe or, in very young piglets, the entire claw, wedges in the slat void leading to pressure and necrosis (KilBride et al., 2009).

As abrasions, sole erosion and injury to the coronary band penetrate the epidermis they provide an entry site for pathogens that can lead to secondary infection in the tarsal, carpal, carpophalangeal, or digital joints, which results in swelling (inflammation) in the joints of the limbs and feet (Penny et al., 1971, Zoric et al., 2004 and KilBride et al., 2009). Such bacterial infections can cause osteomyelitis, arthritis, endocarditis, or meningitis (Penny et al., 1971, Mouttotou and Green, 1999, Zoric et al., 2004, Straw et al., 2006 and KilBride et al., 2009). KilBride et al. (2009) found a relatively low prevalence (5.5%) of swellings but their effect on piglet welfare and performance is severe (KilBride et al., 2012) and so even low prevalence is of concern.

In general a lower incidence of foot and limb injuries is associated with outdoor systems (KilBride et al., 2009). Indoors, the presence of bedding, plastic floors (Furniss et al., 1986, Mouttotou et al., 1999 and Lewis et al., 2005Zoric et al., 2009) and rubber covered floors (Gravås, 1979) are also associated with a lower incidence of lesions. KilBride et al. (2009) investigated the prevalence and risk factors for foot and limb lesions in piglets in England in a number of types of production system including outdoor and indoor systems with straw and indoor systems without bedding. However, in most other countries outside of the UK production systems are more homogenous and intensive; in 95% of EU farms sows farrow in crates whilst the equivalent figure in the UK is 70% (BPEX, 2004 and Johnson and Marchant-Forde, 2009). To date, there has been no large scale study of piglet foot and limb injuries in indoor, predominately slatted systems without the use of straw, as used across the EU. Hence, the aim of the current study was to investigate the prevalence and risk factors for foot and limb lesions in piglets reared in commercial intensive systems in Ireland.

2. Methods

2.1. Farm selection and sample size

Data were collected as part of a cross-sectional survey examining the prevalence and risk factors for lameness, foot and limb lesions in pigs at all stages of the production cycle on Irish farms. Sample size was estimated at 59 farms based on an expected overall prevalence of foot and limb lesions of 95%, a population size of 297 integrated (produced pigs from 'farrow to finish', >100 sows on a single production site) pig farms in Ireland, 95% confidence interval and precision of 5% using Win Episcope 2.0. A total of 68 integrated pig farms were sampled between March 2011 and December 2012. Farms were selected from a database containing information on 98 farms availing of the Teagasc advisory service (PigSys) with a database median (range) herd size of 558 (112–2796) sows.

2.2. Training and biosecurity

All farms were visited by one trained researcher (Amy Quinn [AQ]) and 1–2 research assistants. All animal based measures were scored by the same person (AQ). The main observer (AQ) was trained by an experienced researcher (Laura Boyle [LB]) over 28 days Training involved repeated scoring until over 90% repeatability was reached. A total of seven research assistants also participated in data recording. Training was conducted with each assistant, which included a detailed review of the protocols, demonstrations and practice data collection sessions.

A maximum of 2–3 farms were visited each week depending on the biosecurity practices of the farms. The majority of farmers required the research team to have been away from pigs for 24–72 h prior to visiting their farm. Disposable equipment (e.g. overalls, masks earplugs, gloves) was used where possible and all other equipment (clip boards, torch, measuring tape, electronic distance measure) was thoroughly cleaned and disinfected between each farm visit.

2.3. Measurements

A tour of the farm was provided by a member of the farm staff to familiarise the research team with the farm layout. On each farm, four litters were randomly selected by the researcher for examination using a random number generator, one from each of the following age groups; 3–7 days (d), 8–14 days, 15–21 days and 22–28 days and every piglet in each selected litter was examined. Piglets were lifted for examination of their limbs and feet.

2.3.1. Limb lesions

All four limbs were examined for abrasions, alopecia and swellings and scored as per KilBride et al. (2009) (Fig. 1). Abrasions and alopecia were scored from 0 to 3 as follows: 0 = no lesion, 1 = <25%, 2 = 25–50%, 3 = >50% of the size of the nearest joint on the affected limb. Foot and limb swellings were scored from 0 to 3 as follows: 0 = no lesion, 1 = <25%, 2 = 25–50%, 3 = >50% of the size of the opposing unaffected joint or foot, if joint or foot were bilaterally affected a pig of the same size was used for comparison.

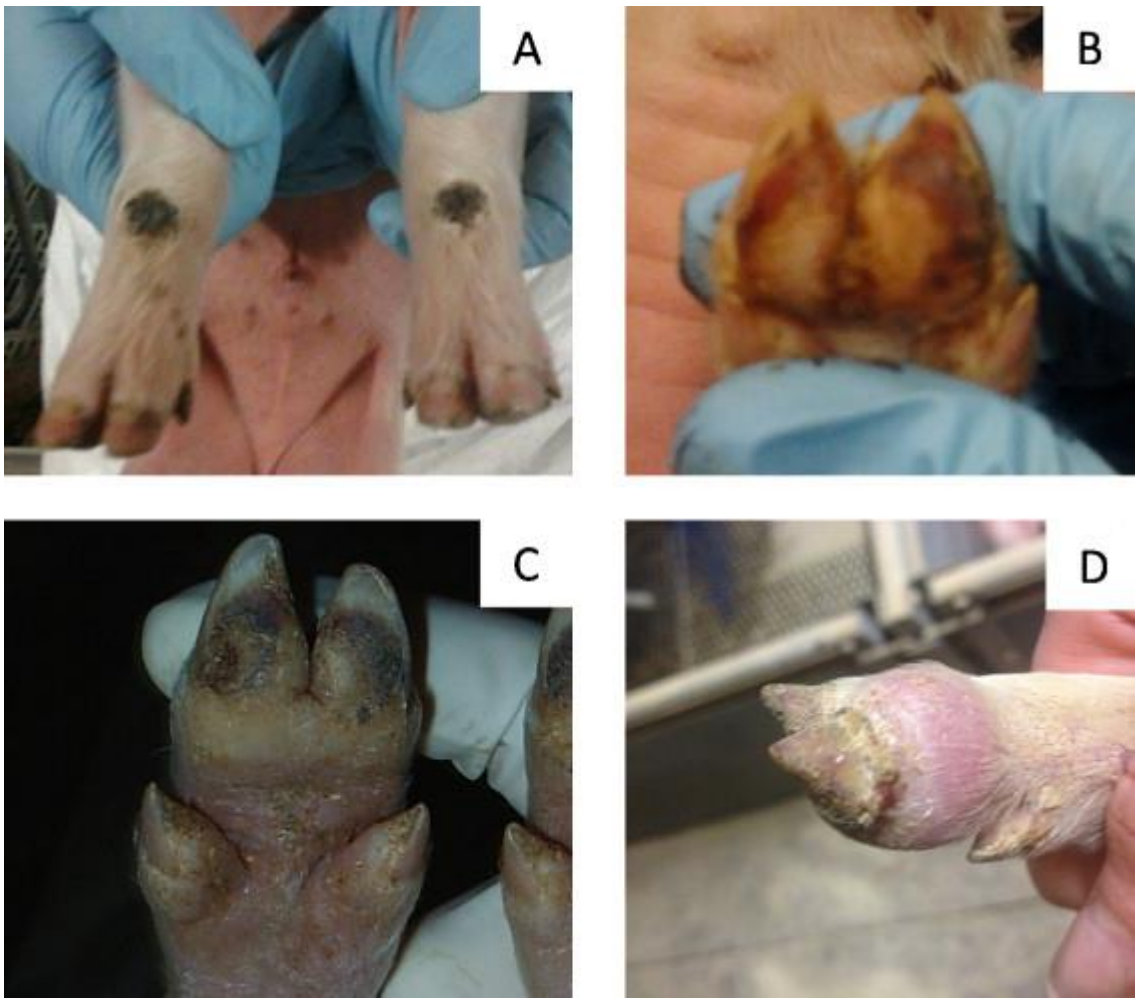

Fig. 1. Image of limb and foot lesions: (A) limb abrasion, (B) sole bruising, (C) sole erosion and (D) swelling and coronary band damage.

2.3.2. Foot lesions

All four feet were examined for swellings, sole bruising and sole erosion (Fig. 1) and scored as per KilBride et al. (2009). Both sole bruising and erosion were scored from 0 to 3 as follows: 0 = no lesion, 1 = <25%, 2 = 25–50%, 3 = >50% of the heel affected. Coronary band injury was defined as disruption to the epidermis at the coronary band presenting as an open or healing wound and it was scored as follows: 0 = no lesion, 1 = <25%, 2 = 25–50%, 3 = >50% of the total coronary band area affected by a lesion (Fig. 1).

2.3.3. Environmental parameters

A detailed diagram of each pen was drawn indicating pen dimensions and the location of resources (e.g. feeder, drinker, slatted area, solid area, crate, heat pad) in each pen (Table 1). Environmental measurements were recorded in the pens in which selected litters were housed.

Table 1. Environmental measurements for piglets.

Pen measurements	Unit / category
Area	
Total area	m^2
Slatted area	m^2
Solid area	m^2
Crate	m^2
Heat pad	m^2
Feeder	m^2
Wall composition	
Material	Concrete, plastic, metal, wood, other
Structure	Fully solid, part solid (+50%), part solid (<50%)
Floor	
Structure	Solid, fully slatted, partially slatted
Material	Concrete, plastic, metal, other
Flooring dimensions	Slat void width, length, inter-void area, shape, profile, edge profile, surface texture
Slopes & steps	Present, absent
Feeders	
Sow feeder	Present, absent
Piglet feeder	Present, absent
Drinker	
Piglet drinker	Present, absent
Sow drinker	Present, absent
Supplementary heat	
Heat pad	Present, absent
Heat lamp	Present, absent
Bedding	Present, absent

2.3.4. Management parameters

A questionnaire was completed on each farm with the farm manager. It comprised 147 questions on animal management routines, breeding policy and genetics, farm performance records, hygiene practices, nutrition and pig health. A copy of the questionnaire is available from the corresponding author.

2.4. Data analysis

Databases were created in Microsoft Access 2003 to store data. Data were checked for outliers prior to analysis. Outliers were checked against the raw data and impossible values were removed.

2.4.1. Calculation of prevalence of lesions

The prevalence of foot and limb lesions was calculated by presence/absence of each lesion per pig and by severity score. The following formula was used to calculate overall prevalence of the lesions:

$$\frac{\text{No. piglets with lesion score} \geq 1}{\text{No. piglets examined on all farms}}$$

The herd prevalence was also calculated to determine the range of lesions between farms. The following formula was used to calculate herd lesion prevalence to determine the range between herds:

$$\frac{\text{No. piglets on farm with lesion score} \geq 1}{\text{No. piglets examined on the farm}}$$

Chi-squared statistics were used to test differences in prevalence and Pearson's correlation coefficient was used to examine correlations between lesions in piglets.

2.4.2. Descriptive analysis of flooring environments

Slat shape and flooring material used for the slatted and solid areas were correlated. As a consequence floor characteristics were grouped into six categories. The farrowing pen was coded into three areas: sow lying area, piglet slatted area, piglet solid area. Descriptions and the distribution of the floor characteristics are shown in Table 2 and Table 3. Foot and limb swellings were combined for regression analysis because of the low number of animals affected (70 and 129 respectively). The solid area of a pen was determined by adding the area of the heat pad, if present, and any other solid area (e.g. piglet solid area) within the pen.

Table 2. The six types of piglet pen floors.

Floor type category	Material used		
	Piglet area slat	Sow area slat	Solid piglet area
Plastic slat, solid plastic	Plastic	Plastic	Plastic
Plastic (oval) and metal slats, solid plastic	Plastic	Metal	Plastic
Plastic (rectangular) and metal slats, solid plastic	Plastic	Metal	Plastic
Metal slat, solid plastic	Metal	Metal	Plastic
Metal slat, metal solid	Metal	Metal	Metal
Other slats, solid concrete	Metal, concrete, plastic	Metal, concrete, plastic	Concrete

Table 3. Number (n) and percentage (%) of piglets by type of floor.

Floor type	n	%
Plastic slat, solid plastic	675	22.9
Plastic (oval) and metal slats, solid plastic	283	9.6
Plastic (rectangular) and metal slats, solid plastic	545	18.5
Metal slat, solid plastic	548	18.6
Metal slat, metal solid	320	10.9
Other slats, solid concrete	577	19.6

2.4.3. Mixed effect binomial regression models

Data were analysed using MlwiN 2.27 (Rasbash et al., 2012). Multilevel mixed effect logistic regression was used to allow for pigs clustered in litters within farms and therefore a three level random effect model was used. All continuous variables were transformed to categorical variables and checked for linearity, if a linear association was found the continuous variable was used, otherwise the categorical version was used. Predictor variables were screened in the univariable analysis and those with a significance of $P < 0.2$ were used to develop the multivariable model. They remained in the final model if they were significant at $P \leq 0.05$. If variables were highly correlated the variable that made the most biological sense was left in the model. Then to check for residual

confounding all variables not in the model, including those with P > 0.2 in the univariable analysis were retested in the model. The following model was used:

$$Logit(pijk)=\beta0+\sum\beta xijk+\sum\beta xjk+\sum\beta xk+vk+ujkLogit(pijk)=\beta0+\sum\beta xijk+\sum\beta xjk+\sum\beta xk+vk+ujk$$

pijk = the proportion of the litter that were affected (score ≥ 1) with the lesion being investigated, Logit = logit link function, β0 = constant, βx = vector of fixed effects varying at level 1 (ijk), level 2 (jk), or level 3 (k), i = piglet, j = pens (i.e. litter), k = farms, vk = level 3 residual variance, ujk = the level 2 residual variance. Interactions we not investigated due to the relatively small sample size and high number of predictor variables. When the prevalence of lesions in a litter was low or high (<5% or >95%) logistic regression was not carried out. Model fit was visually assessed for each of the models by comparing the expected and observed data.

3. Results

3.1. Farm features

A total of 2948 piglets (3–7 days = 757; 8–14 days = 753; 15–21 days = 727 and 22–28 days = 711 piglets) were examined from 272 litters. The overall mean litter size was 10.9 (SD ± 1.5), with a mean litter size per age category of 3–7 days = 11.1 (SD ± 1.4); 8–14 days = 11.1 (SD ± 1.4); 15–21 days = 11.0 (SD ± 1.4) and 22–28 days = 10.5 (SD ± 1.7) piglets. Litter size was determined based on the number of live piglets in the pen at time of inspection. All piglets were housed indoors in farrowing pens consisting of a farrowing crate and a piglet area on a variety of floor types, bedding was not provided in any form on any of the farms (Fig. 2). The mean pen area was 4.0 m2 (±0.3) with a mean slat width of 11 mm (±3) and void width of 10 mm (±1.5) in the piglet area and a slat width of 18 mm (±10) and void width of 12 mm (±5) in the sow area.

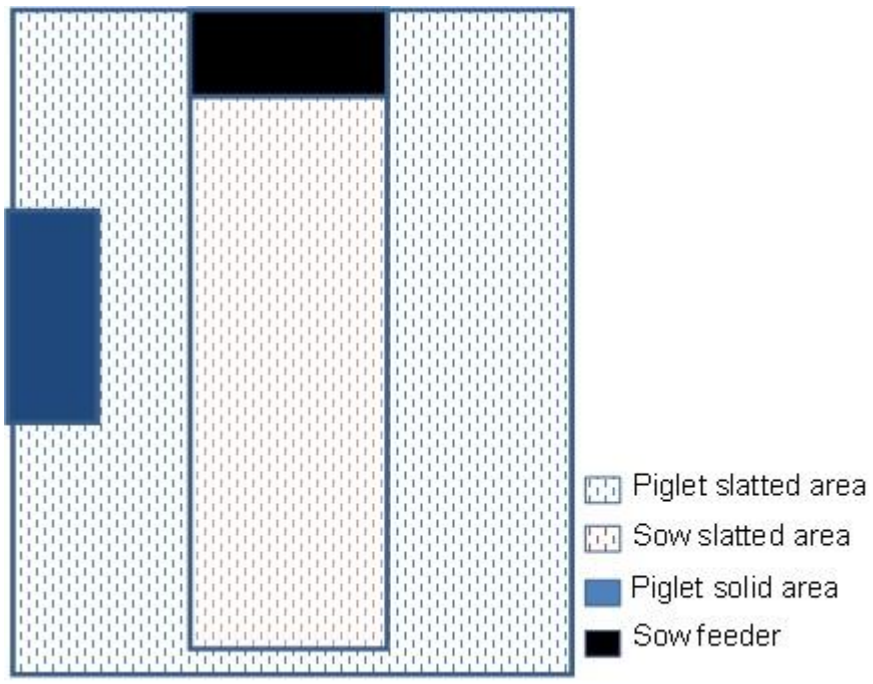

Fig. 2. Farrowing crate "typical design" based on average dimensions.

3.2. Prevalence of foot and limb lesions

The prevalence of sole bruising, sole erosion, coronary band injury, limb abrasions, alopecia, swollen limbs and swollen feet in 2948 piglets was 61.5%, 34.1%, 11.3%, 55.7%, 24.8%, 2.3% and 4.4% respectively. There was a wide range in the prevalence of foot and limb lesions between farms: sole bruising (7–100%), sole erosion (0–100%), coronary band damage (0–46%), foot swelling (0–14%), limb abrasions (11–98%), alopecia (0–83%) and limb swelling (0–11%).

The prevalence of foot and limb lesions varied between the front and hind limbs and feet (Table 4). Limb abrasions were more prevalent on front (54.7%) than on hind (6.7%) limbs. Injury to the coronary band was slightly more prevalent on front than on hind feet (8.4% vs. 4.9%) as was sole bruising (55.1% vs. 48.4%). There was no significant difference in the prevalence of lesions between the left and right limbs and feet. The distribution of lesions by severity score varied by lesion type. When present, sole bruising, sole erosion and coronary band injuries were mainly score 1 whilst, the modal score for limb abrasions and alopecia was 2. The prevalence of foot and limb lesions varied by age and pen floor type (Table 5).

Table 4. Number (n) and prevalence (%[a]) of lesions on piglet front and hind limbs with lesion present (score ≥ 1) and by severity score.

	Present		Score 1		Score 2		Score 3	
	n	%	n	%	n	%	n	%
Sole bruising	1863	61.5	1277	41.6	487	16.5	99	3.4
Front limbs	1624	55.1	1167	39.6	392	13.3	65	2.2
Hind limbs	1426	48.4	1044	35.4	329	11.2	53	1.8
Sole erosion	1005	34.1	576	19.5	321	10.9	108	3.7
Front limbs	689	23.4	437	14.8	195	6.6	57	1.9
Hind limbs	793	26.9	475	16.1	241	8.2	77	2.6
Coronary band injury	333	11.3	185	6.3	91	3.1	57	1.9
Front limbs	248	8.4	135	4.6	71	2.4	42	1.4
Hind limbs	143	4.9	94	3.2	32	1.1	17	0.6
Foot swelling	129	4.4	44	1.5	47	1.6	38	1.3
Front limbs	84	2.9	28	1.0	33	1.1	23	0.8
Hind limbs	49	1.7	17	0.6	15	0.5	17	0.6
Limb abrasion	1641	55.7	424	14.4	757	25.7	460	15.6
Front limbs	1612	54.7	416	14.1	752	25.5	444	15.1
Hind limbs	198	6.7	117	4.0	53	1.8	28	1.0
Alopecia	731	24.8	176	6.0	352	11.9	203	6.9
Front limbs	704	23.9	168	5.7	338	11.5	198	6.7
Hind limbs	70	2.4	23	0.8	23	0.8	24	0.8
Swollen limb	67	2.3	27	0.9	30	1.0	10	0.3
Front limbs	44	1.5	13	0.4	16	0.5	15	0.5
Hind limbs	29	1.0	11	0.4	7	0.2	11	0.4

[a] Severity percentages may not add to total due to rounding.

Table 5. Prevalence (%) and number of piglets affected (score ≥1) with sole bruising, sole erosion, coronary band injury, foot swellings, limb abrasions, alopecia and limb swellings by age and floor types.

	Sole bruising		Sole erosion		Coronary band injury		Foot swelling		Limb abrasion		Alopecia		Limb swelling	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Age														
3-7d	667	87.9	264	34.8	146	19.2	32	4.2	321	42.3	57	7.5	8	1.1
8–14d	521	69.3	265	35.2	82	10.9	30	4.0	370	49.2	129	17.2	9	1.2
15–21d	348	47.9	234	32.2	47	6.5	24	3.3	421	58.0	260	35.8	24	3.3
22–28d	277	39.0	242	34.0	58	8.2	43	6.1	529	74.4	285	40.1	29	4.1
Floor types														
Plastic slat, solid plastic	427	63.3	209	31.0	58	8.6	23	3.4	351	52.0	130	19.3	11	1.6
Plastic (oval)and metal slats, solid plastic,	103	36.4	51	18.0	16	5.7	11	3.9	109	38.5	38	13.4	6	2.1
Plastic (rectangular) and metal slats, solid plastic	377	69.2	131	24.0	51	9.4	26	4.8	308	56.5	103	18.9	16	2.9
Metal slat, solid plastic	372	67.9	252	46.0	78	14.2	32	5.8	336	61.3	135	24.6	19	3.5
Metal slat, metal solid	183	57.2	139	43.4	75	23.4	15	4.7	174	54.4	126	39.4	6	1.9
Other slats, solid concrete	351	60.8	223	38.7	55	9.5	22	3.8	363	62.9	199	34.5	12	2.1

3.3. Risk factors for foot and limb lesions

Model fit was acceptable by visual inspection.

3.3.1. Sole bruising

The risk of sole bruising decreased with age. There was a lower risk of sole bruising in piglets in pens with plastic oval slats in the piglet area and metal slats under the sow with a solid plastic area when compared with piglets in pens with plastic slats throughout and a plastic solid area for piglets (Table 6).

Table 6. Multilevel mixed effect binomial regression models of the risks associated with presence of sole bruising, sole erosion, coronary band injury, limb abrasions and foot and limb swellings in piglets.

	Sole bruising			Sole erosion			Coronary band injury			Limb abrasion			Alopecia			Limb & foot swellings		
Intercept coefficient	2.67			0.3			-1.56			-0.29			-3.3			-0.82		
	OR	CI		OR	CI		OR	CI		OR	CI		OR	CI		OR	CI	
Age	0.42	0.37	0.50	0.97	0.88	1.06	0.69	0.60	0.81	1.54	1.12	2.14	1.19	1.04	1.36	1.25	1.06	1.47
Floor type																		
Plastic slat, plastic solid																		
Plastic (oval) & metal slats, solid plastic	0.32	0.15	0.70	1.19	0.69	2.07	0.59	0.22	1.59				0.68	0.30	1.53	1.32	0.58	3.00
Plastic (rectangular) & metal slats, solid plastic	1.70	0.88	3.28	1.93	1.13	3.30	1.02	0.46	2.24				0.17	0.09	0.34	1.59	0.82	3.08
Metal slat, plastic solid	1.32	0.72	2.41	1.92	0.62	5.93	1.74	0.87	3.51				1.16	0.63	2.12	1.90	1.01	3.58
Metal slat, metal solid	0.95	0.47	1.91	1.54	0.82	2.90	4.25	1.96	9.22				2.59	1.30	5.15	1.33	0.62	2.86
Other slats, solid concrete	1.24	0.69	2.23	1.79	1.04	3.08	1.23	0.61	2.50				1.62	0.91	2.90	1.28	0.67	2.46
Heat pad present																		
Yes				0.3	0.2	0.6												
No																		
Random effects	Var		SE	Var		SE	Var		SE	Var		SE	Var		SE	Var		SE
Farm	0.6		0.17	1.2		0.24	0.8		0.23	0.5		0.12	0.7		0.17	0.3		0.15
Pen	0.9		0.14	0.3		0.07	0.8		0.18	0.5		0.09	0.7		0.13	0.6		0.21

3.3.2. Sole erosion

There was no association between sole erosion and age. There was an increased risk of sole erosion in piglets in pens with plastic rectangular slats in the piglet area and metal slats under the sow with a solid plastic area and for piglets in pens which had an other slatted area and a concrete solid area when compared to pigs in pens with plastic slats throughout and a piglet plastic solid area. The other category comprised of a variety of concrete, metal and plastic combinations. The risk of sole erosion decreased when a heat pad was present (Table 6).

3.3.3. Coronary band injury

The risk of coronary band injury decreased with age. There was an increased risk of coronary band injury in piglets in pens with metal slats throughout with a piglet metal solid area when compared to pigs in pens with plastic stats throughout and a piglet plastic solid area (Table 6).

3.3.4. Limb abrasion

The risk of limb abrasions increased with age. There was no significant association between limb abrasions and floor type (Table 6).

3.3.5. Alopecia

The risk of alopecia increased with age. There was a decrease in the risk of alopecia in piglets in pens with plastic rectangular slats in the piglet area and metal slats under the sow with a solid plastic area and an increased risk in piglets in pens with metal slats throughout with a piglet plastic solid area when compared to pigs in pens with plastic slats throughout and a piglet plastic solid area.

3.3.6. Foot and limb swellings

The risk of foot and limb swellings increased with age. There was an increased risk of foot and limb swellings in piglets in pens with metal slats throughout with a piglet plastic solid area when compared with piglets in pens with plastic stats throughout and a piglet plastic solid area (Table 6). There was an increased risk of foot and limb swellings when sole erosion (OR 1.60, CI 1.14, 2.24), coronary band injury (OR 4.01, CI 2.78, 5.80) and limb abrasions (OR 1.72, CI 1.21, 2.43) were present.

3.3.7. Correlations between lesions

Several foot and limb lesions were correlated to one another (Table 7). Key associations were a positive association between limb abrasions and limb joint swellings and a positive association between sole erosion and coronary band injury and foot swelling.

Table 7. Significant corelations between piglet foot and limb lesions.

	Limb swelling	Foot swelling	Sole bruising	Sole erosion	Coronary band injury	Limb abrasion	Alopecia
Limb swelling	1						
Foot swelling	0.09***	1					
Sole bruising	-0.06**	0.02	1				
Sole erosion	0.02	0.11***	0.19***	1			
Coronary band injury	0.01	0.21***	0.01	0.12***	1		
Limb abrasion	0.08***	0.04*	-0.01	0.07**	0.05*	1	
Alopecia	0.8***	0.11***	-0.06**	0.09***	-0.03	0.05*	1

* = <0.05, ** = <0.005, *** = -<0.0001

4. Discussion

This is the first study to examine the prevalence and risk factors for foot and limb lesions in piglets on commercial farms in Ireland and it is the largest cross sectional study to date of indoor housing systems. This survey examined 24% of Irish pig farms and is representative of herd sizes and geographic locations of Irish pig farms. However the farms were sourced from a database of clients of the Teagasc advisory service and so the results collected may be biased towards herds that are more production and health focused since they were using advice from pig specialists on a regular basis. This could mean that the findings underestimate the national prevalence of the lesions examined.

This is the first cross-sectional study to determine the prevalence and risk factors of coronary band injuries. However a previous study has indicated that straw provision reduces the occurrence of this lesion (Westin et al., 2014). In the current study, the negative association with increasing age is likely due to a combination of healing lesions and increasing resilience over time and reduced incidence of occurrence with increasing size and resilience of the foot as the piglet gets older which makes it less likely to become trapped in the voids between the slats (KilBride et al., 2009). There was an increased risk of coronary band injury in pens with metal slats throughout with a metal solid area for piglets when compared to the other floor types. Metal is a more unyielding material than plastic and therefore applies more pressure to the coronary band if the foot becomes caught in the void between the slats and this might explain the increased risk of injury (Gregory, 2007; KilBride, 2008).

As reported in other studies, sole bruising was the most prevalent foot lesion, although there was an even higher prevalence of sole bruising in the current study (62%) than in Mouttotou et al. (1999) (50%) and KilBride et al. (2009) (49%). This might be explained by the absence of outdoor farms and farms with solid floors with bedding in the current study, which was associated with a reduced risk of sole bruising in the previous studies and that all the floors in the current study were slatted, at least in part, which was associated with a higher prevalence of sole bruising (Mouttotou et al., 1999, KilBride et al., 2009 and Westin et al., 2014). The negative association between sole bruising and age is probably because the epithelium of the sole at birth is only 1–2 mm deep (KilBride et al., 2009) and thickens as the piglets age thereby making the sole less susceptible to bruising (KilBride et al., 2009). In the current study, the risk of sole bruising decreased when the floors had plastic oval slats in the piglet area, metal slats in the sow area and a piglet solid plastic area when compared to pens with fully plastic rectangular slats with a piglet plastic solid area. This is possibly due to a more even distribution of weight to the foot pad provided by an oval compared to a rectangular shaped void, reducing pressure on specific points of the foot.

KilBride et al. (2009) also suggested an alternative hypothesis to reduction in sole bruising with age, which is that sole bruising is replaced by sole erosion (when the epidermal layers of skin are removed) in harsh environments and so bruising will no longer be present. There was a high prevalence of sole erosion in the current study (34%) in comparison to KilBride et al. (2009) (17%) and it was most strongly associated with sole bruising. This is a serious welfare concern as this injury, along with injury to the coronary band, is associated with pain and both can act as an entry site for bacteria and result in infection and joint swelling (Penny et al., 1971, Mouttotou and Green, 1999 and Straw et al., 2006). The risk of sole erosion increased in piglets in pens with rectangular plastic and metal slats and a piglet plastic solid area when compared to piglets in pens with entirely plastic slats and a piglet plastic solid area. Metal slats are considerably more abrasive than plastic slats

(Gregory, 2007), thus exposure to a more abrasive floor type resulted in and increased risk of sole erosion. The risk of sole erosion also decreased when a heat pad was present. Mouttotou and Green (1999) reported that the protective benefit of a heat pad is related to the fact that piglets use these areas of the pen more because of increased comfort and warmth and therefore spend less time in the potentially more injurious parts of the pen i.e. the slatted sow area.

Given the high susceptibility of piglets to coronary band injuries and sole bruising at young ages it is possible that such lesions might be prevented by housing piglets on softer flooring for the first week of life. On the other hand this could merely delay the onset of bruising and coronary band injury to a later age (KilBride et al., 2009).

Skin abrasions were the most prevalent limb lesion and they occurred most commonly bilaterally on the carpus of the front limbs, as previously reported (Gravås, 1979; Svendsen et al., 1979; Mouttotou and Green, 1999, Mouttotou et al., 1999, Zoric et al., 2004, Zoric et al., 2008 and KilBride et al., 2009). In the current study limb abrasions increased with age, this is in contrast to previous studies (Svendsen et al., 1979; Phillips et al., 1996; Mouttotou and Green, 1999, Mouttotou et al., 1999, Zoric et al., 2004 and KilBride et al., 2009). However, the lack of bedding provision and floor types sampled are different from these studies. The unusual trend in the current study might also be because any epidermal disruption was considered a skin abrasion and the stage of the lesion (i.e. fresh or healing) was not recorded. In the current study, there was no association between the prevalence of limb abrasions and pen floor type. This agrees with KilBride et al. (2009) where a lower risk of occurrence was only associated with outdoor systems and Mouttotou et al. (1999) and Zoric et al. (2009) where a lower risk of skin abrasions on solid concrete floors and with bedding as opposed to pens with slatted floors, which included all the farms in the current study. That is, there was insufficient variation in floor type to observe a difference in prevalence of limb abrasions.

In the current study alopecia was more common on front than hind limbs, similar to Mouttotou and Green (1999) and KilBride et al. (2009), and increased with age. One explanation for alopecia is that it is formed from hairless scar tissue after a limb abrasion has healed (Wechsler et al., 2000, KilBride, 2008 and Zaffino, 2012). Hairless patches may also present on piglets as a mild lesion when pen conditions lead to less damage to the skin than an abrasion. The former explanation is more likely in piglets in the current study.

Overall, in the current study, there was a relatively low prevalence of foot and limb swellings (6.8%) when compared with the other lesions observed. The prevalence is similar to KilBride et al. (2009). KilBride et al. (2009) reported that internal pathological damage was often more severe than external injuries suggested and internal infection often did not result in noticeable swelling and so swellings may underestimate the prevalence of internal infections in the foot and limb. The severity of swellings therefore makes them a production and welfare concern despite their low prevalence (Penny et al., 1971, Zoric et al., 2004 and KilBride et al., 2009). Metal slats are considerably more abrasive than plastic slats (Gregory, 2007), so it is not surprising that the risk for foot and limb swellings increased in pigs in pens with metal slats throughout with a small plastic solid floor area for piglets. There was an increased risk of foot and limb swellings when sole erosion, coronary band injury or limb abrasions were present. These three lesions penetrate the epidermis and so provide an entry site for pathogens which can result in infection and associated swellings (Penny et al., 1971, Mouttotou and Green, 1999 and Straw et al., 2006). The level of correlation is low but significant due to the large sample size.

Whilst no one floor type was ideal in the current study, avoiding the use of metal slats in both the piglet and sow areas of the farrowing pen could reduce the occurrence of coronary band lesions, sole bruising, sole erosion and foot and limb swellings. These lesions are associated with the most potential for negative welfare impact.

There were no management variables significantly associated with foot and limb lesions in the current study. This is probably due to the lack of variation in management and general housing of piglets on commercial pig units in Ireland. A limitation of this study design is the difficulty associated with determining cause and effect with cross-sectional studies. However, these piglets were in one environment from birth and so associations with the environment are likely to be causal or on the causal pathway. Sampling of a range of ages of piglets and observing trends with age indicate that for some environments there was a dose effect (time exposed), which increases the concern about the damage caused by some environments.

5. Conclusions

The high prevalence of foot and limb lesions in commercial farms in Ireland is a substantial welfare concern. Whilst no single floor type in this sample of Irish pig farms was consistently associated with low levels of piglet foot and limb lesions, metal slats were associated with an increased risk of coronary band injury, sole bruising and erosion and these in turn were associated with swellings of foot and limb joints. We conclude that avoiding the use of metal slats in both the piglet and sow areas of the farrowing pen could reduce the occurrence of these lesions which can contribute to infection in foot and limb joints.

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