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# Influence of floor surface and access to pasture on claw health in dairy cows kept in cubicle housing systems

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ABSTRACT

In this study, the effects on the claw health of dairy cows of three different floor types and access to pasture were investigated on 35 farms. The farms were fitted with a given floor type in the indoor walking area of a cubicle housing system: a solid rubber, mastic asphalt or slatted concrete floor. Because we chose farms on which the given floor type was in good condition, the data presented show what can be achieved on these types of floors under ideal circumstances. Cows on half of the farms per floor type had access to pasture during the grazing period. Each farm was visited three times at approx. 6-month intervals at the end of the winter indoor-housing period and at the end of the summer period, i.e. after the period with access to pasture on half of the farms. During each visit, the claw health of the same 10 cows per farm was assessed on the occasion of routine claw trimming. The proportion of cows with haemorrhages increased from mastic asphalt to rubber and slatted concrete floors. A lower proportion of cows kept on mastic asphalt was affected by white-line fissures and needed intermittent claw-trimming, an indicator for lameness. Cows housed in cubicle systems with slatted concrete floors were at the lowest risk of having heel-horn erosions. Access to pasture was associated with a lower incidence of slight white-line fissures and dermatitis digitalis. A higher proportion of cows with sole haemorrhages and sole ulcers were found on all floor types at the end of the summer period than at the end of the winter indoor-housing period. Floor type did not influence the presence of sole ulcers and deep white-line fissures. In conclusion, the effect of floor type on claw health was slight, and none of the investigated floor types was clearly superior to the others. Access to pasture was not effective in reducing the presence of most types of claw lesions associated with the floor type used in the indoor walking area.

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## 1. Introduction

Claw lesions and lameness are widespread in dairy-cow herds (Vermunt, 2005) and considered to be an important animal-welfare problem, associated as they are with pain (O'Callaghan et al., 2003) and disturbed behaviour (Hassall et al., 1993). Additionally, there is a severe impact on productivity (Archer et al., 2010) and economy (Cramer et al., 2009; Ettema et al., 2010). External traumata due to poor floor quality (Chesterton, 1989; Cook and Nordlund, 2009) are regarded as one of the trigger factors for lesions such as sole haemorrhages, sole ulcers and white-line fissures. An adequate floor type is therefore important for the improvement of claw health in dairy cows.

Slatted concrete floors and mastic asphalt are hard-floor types that can lead to high mechanical pressures on the

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claws, resulting in claw lesions (Van der Tol et al., 2002). Furthermore, hard floors are often excessively abrasive or slippery, thereby increasing the presence of claw damage and leg fractures (Webb and Nilsson, 1983). On the other hand, manure is well drained on slatted concrete floors, which is advantageous in terms of reducing the presence of heel-horn erosion (Thysen, 1987). Although the influence of mastic asphalt on claw health has hardly been investigated (but see Telezhenko, 2007), there are anecdotal reports from farmers that excessively rough mastic-asphalt floors result in the thinning of the claw sole (Pahlke, 2004; Schneider, 2006).

In recent years, the use of rubber floors in the walking area of dairy-cow housing systems has been investigated as an alternative to hard floors. Initial studies have shown that claw lesions occur less frequently on slatted and solid rubber floors than on slatted and solid concrete floors (Benz, 2002; Vanegas et al., 2006; Bell and Huxley, 2009). There are, however, other findings indicating that rubber floors have a negligible effect on claw health (Boyle et al., 2007; Kremer et al., 2007) and that rubber floors may not mitigate the effects of claw lesions (Krebs et al., 2011). Moreover, cows were found to spend more time standing and walking in passageways with a rubber floor (Kremer et al., 2007), which was presumed to lead to a higher prevalence of infectious claw diseases, e.g. dermatitis digitalis (Kremer et al., 2007).

In addition to the floor quality of the indoor walking area, access to pasture may have effects on claw health. Several studies have found beneficial effects of pasturing on claw health of dairy cows kept in tie-stalls (Bendixen et al., 1986; Loberg et al., 2004) and on lameness in cows housed in free-stall barns (Haskell et al., 2006; Hernandez-Mendo et al., 2007).

The present multi-farm study aimed to examine the effects of three floor types (solid rubber floor, mastic asphalt, slatted concrete floor) when they are in a good state on the claw health of dairy cows kept in cubicle housing systems. A further aim of this study was to investigate whether outdoor exercise on pasture can mitigate the potential negative effects on claw health of the floor in the walking area of a cubicle housing system.

## 2. Materials and methods

### 2.1. Investigated farms

Cow claw health was assessed on 35 dairy farms with cubicle housing systems. On these farms, the floor surface of the indoor walking area consisted either of mastic asphalt (12 farms), slatted concrete (11 farms), or solid rubber (12 farms). With each floor type, cows on half of the farms (5 farms with slatted concrete floor) had access to pasture in summer during the grazing period for several hours a day (2.5–8 h, median 4 h). Moreover, on 18 farms with and four farms without access to pasture, cows had access to an outdoor run. The mean number of lactating cows per herd was 52, with a range of 18–140 cows. Cows of breeds selected for high milk yield (Holstein, Red Holstein, Brown Swiss and their cross breeds) were present on 32 farms, and Simmental cows were kept on three farms. Average annual milk yield per cow on the farms studied was 7928 kg. Table 1 lists information on breeds, herd size, milk yield, accessibility and floor type of outdoor runs, age and cleaning frequency of the floors, and diet on the investigated farms.

As we were interested in the effects of the different floor types on claw health and aimed to investigate the potential achievement on farms with floors in a good state, we excluded from our study all dairy holdings identified by the farmer in question as having problems with the flooring (e.g. construction defects, too slippery, too rough). This allowed us to directly compare the different floor types without using their actual state as a confounding variable.

To recruit and select the study farms, claw trimmers, agricultural consultants and vendors of specific floor types had been asked to suggest potential farms (with access to pasture: $N = 115$; without access to pasture: $N = 40$). In a first step, farmers were interviewed, and a number of farms ruled out on the basis of these oral reports. Farmers were asked whether cows were observed to slip in the indoor walking area, whether they showed clear oestrus behaviour, and whether there were general problems in respect to claw health or other aspects of animal health. These questions aimed at excluding farms on which the floor was not in an adequate condition (e.g. too slippery, too rough) as well as farms with known general health problems. If all answers were no, the farm was visited (with access to pasture: $N = 30$; without access to pasture: $N = 19$) and directly assessed by the first author (HCH) in respect to the quality of the floor in the cubicle housing system. The final decision of whether or not to include them in the study was made on site. Age of the floor was not a criterion for exclusion.

### 2.2. Assessment of claw lesions

On each farm, claw lesions of 10 individual cows with parity 2–6 were recorded 3 times at approx. 6-month intervals. The cows had been selected in the expectation that they would remain in the herd for the duration of the study. So as to exclude animals with a possible predisposition to claw lesions, cows were not considered if they had suffered from a serious disease such as ketosis or displaced abomasum within the 6 months preceding the study. Inspection of the claws was always carried out by the first author during routine claw trimming, which was performed by the farm's usual claw trimmer, with no restrictions imposed by the study design. Farms were visited at the end of both the winter indoor-housing period and the summer period, i.e. after the period with access to pasture on half of the farms. Data collection on these farms began at the end of the summer period in autumn 2006, whilst farms without pasture were first visited at the end of the winter period in spring and summer 2007. For organisational reasons, one farm with a slatted concrete floor (with access to pasture) and one farm with a mastic asphalt floor (without access to pasture) were only visited twice, whilst one farm with a slatted concrete floor (without access to pasture) was only visited once.

Claws of all four legs of the selected cows were examined for sole ulcers, sole haemorrhages, slight and deep

**Table 1**
Characteristics of the investigated farms.

| Floor type in the walking area | Rubber | Rubber | Mastic asphalt | Mastic asphalt | Slatted concrete | Slatted concrete |
|---|---|---|---|---|---|---|
| Number of herds | 6 | 6 | 6 | 6 | 5 | 6 |
| Access to pasture | Yes | No | Yes | No | Yes | No |
| Number of herds with cows of the following breeds | | | | | | |
| Brown Swiss | 4 | 4 | 4 | 3 | 2 | 3 |
| Holstein Frisian | 1 | 2 | 1 | 1 | 2 | 1 |
| Red Holstein | 1 | 0 | 1 | 1 | 1 | 0 |
| Simmental | 0 | 0 | 0 | 1 | 0 | 2 |
| Herd size | | | | | | |
| Min–max | 18–44 | 42–140 | 27–58 | 46–80 | 25–46 | 40–70 |
| Median | 33 | 70 | 35 | 68 | 36 | 61.5 |
| Average annual milk yield (in kg) per cow and herd | | | | | | |
| Min–max | 6790–8280 | 7243–10,532 | 5507–9064 | 7000–9500 | 6710–9068 | 6700–9269 |
| Median | 7304 | 8184 | 7463 | 8389 | 7567 | 8463 |
| Access to outdoor run | | | | | | |
| No access | 0 | 6 | 0 | 4 | 0 | 4 |
| Permanent | 4 | 0 | 5 | 2 | 4 | 0 |
| Restricted | 2 | 0 | 1 | 0 | 1 | 2 |
| Floor type of outdoor run | | | | | | |
| Slatted concrete | 4 | 0 | 2 | 0 | 1 | 0 |
| Concrete | 2 | 0 | 1 | 2 | 3 | 2 |
| Mixed | 0 | 0 | 2 | 0 | 0 | 0 |
| Wood chips | 0 | 0 | 1 | 0 | 0 | 0 |
| Compacted soil | 0 | 0 | 0 | 0 | 1 | 0 |
| Age of the floor in years | | | | | | |
| Min–max | 1–3 | 1–3 | 2–25 | 1–10 | 2–17 | 8–22 |
| Median | 1.5 | 2 | 4.5 | 3 | 4.5 | 11 |
| Cleaning frequency of the floor per day | | | | | | |
| Min–max | 2–5 | 4–12 | 2–6 | 4–8 | 0–1 | 0–2 |
| Median | 4 | 6 | 3 | 7 | 0 | 2 |
| Diet | | | | | | |
| Hay-/silage-based | 2/4 | 0/6 | 3/3 | 0/6 | 3/2 | 0/6 |

white-line fissures, heel-horn erosions and dermatitis digitalis and assessed according to a system of severity codes. Based on Brizzi et al. (1998) each claw was differentiated into several zones. Because of the rare presence of each of the diagnostic findings at the different severity codes in each zone and the rare overall presence of most of the diagnostic findings we decided to simplify our data set to presence–absence of each diagnostic finding at a given visit in a given cow. Sole ulcers included ulcerations of the sole, toe or heel and abscesses of the white line and three levels of severity were differentiated depending on the diameter of the ulcer (<5, 5–10, >10 mm). Sole haemorrhages were identified by discolorations ranging from light- to dark-red and violet covering less than half, more than half or the complete affected claw zone. Deep white-line fissures were separations of the white line requiring removal of the overlying wall horn when claws were trimmed (removal of the wall horn Ø 10 mm, Ø 10–25 mm or Ø >25 mm). Slight white-line fissures were defined as separations of the white line that disappeared with a cut beneath normal claw-trimming level (length of fissure <10 mm, 10–20 mm or >20 mm). Heel-horn erosions included superficial horn defects, light grooving of the heel horn and large fissures extending to the corium. Dermatitis digitalis included classic lesions of the digital skin characterised by a red, granular, strawberry-like surface, as well as ulcerative forms.

Data from a total of 908 claw assessments (331, 310 and 267 at the first, second and third visit, respectively) of 339 cows were complete in respect to all explanatory variables and could thus be included in the analysis. Over the course of the study, 7 cows were culled or left the herd for other reasons after the initial examination. These cows were replaced by animals with similar characteristics in terms of lactation number and breed. Replacement cows were handled in the statistical analyses as animals different from those which were replaced. Cows leaving the herd after the second claw-health examination were not replaced for the assessment in the third visit. Although 55 cows (26 on rubber floors, 16 on mastic asphalt, 13 on slatted concrete floors) underwent 63 additional claw treatments (30 on rubber floors, 17 on mastic asphalt, 16 on slatted concrete floors) during data collection in between routine claw trimming, their claws were still checked for lesions at the subsequent routine claw trimming, the data of which were included in the analysis. The necessity of intermittent claw trimmings was also analysed as an indicator for the presence of lameness.

### 2.3. Statistical analysis

Binary data of individual animals (occurrence of health risks) were analysed with a generalized linear mixed model. The binary data are following a Bernoulli distribution, with a probability $p$ for, e.g. haemorrhages. The model comprised fixed and random effects on the logit scale for the probabilities $p$, i.e. $\text{logit}(p) = \log(p/(1-p))$ was modelled as a sum of fixed and random effects. Random effects comprised random cow effects, nested within random farm effects. A general correlation structure was assumed for the random cow effects for the three visits to a farm. Fixed effects (initially) comprised main effects and two factor interactions for floor types, access to pasture or not, and seasons.

Estimation was based on approximate maximum likelihood, employing Laplace integration as implemented in the lme4 package (Bates et al., 2011) from R 2.13.2 (R Development Core Team, 2011). Hypothesis tests were based on the likelihood ratio test, with the conventional chi-square approximation.

We report the risk of the presence of the subclinical findings based on odds-ratios (OR). In the case of generalised mixed-effects models one needs to differentiate between subject-specific ORs, representing the situation as if one farm shifted from one floor type to another (i.e. keeping all random effects constant) and the marginal effect that can be expected for any given farm (i.e. averaging over farms: shrinkage, see e.g. Diggle et al., 2002). We used the formula proposed there to calculate the marginal ORs based on the subject-specific ORs.

## 3. Results

The risk for haemorrhages increased from cows kept on mastic asphalt to those kept on rubber flooring and further to the cows kept on slatted concrete (Table 2). At the end of the summer period the risk for haemorrhages was higher than at the end of the winter.

The risk for sole ulcers was elevated slightly at the end of the summer compared to the end of the winter on mastic asphalt and especially on rubber flooring but remained on a similar level on slatted concrete. There was no strong difference in the risk for sole ulcers between the floor types in either season nor between farms with or without access to pasture (Table 2).

Whereas the risk of deep white-line fissures did not seem to be influenced by our design variables (apart from a tendency for an increased risk at the end of the summer; Table 2), fewer cows with slight white-line fissures were found on both mastic asphalt and slatted concrete floors than on rubber floors in summer. Additionally, the risk for slight white-line fissures was lowest on mastic asphalt after the winter season. Moreover, the proportion of cows with slight white-line fissures was lower on farms with access to pasture when access was granted in the summer period (Table 2).

Heel horn erosions occurred slightly more rarely on mastic asphalt than on rubber floors and were even rarer on slatted concrete (Table 2). Also, the prevalence of heel horn erosions was smaller at the end of the summer compared to the end of the winter.

Dermatitis digitalis occurred relatively often on slatted concrete on farms without access to pasture and was specifically rare on the same floor on farms with access to pasture whereas there was no effect of season (Table 2).

The prevalence of any of these subclinical findings was high (>90%, Table 2) and was not related to floor type though a relatively low risk could be observed at the end of summer on farms with access to pasture.

Intermittent claw treatments were relatively rare (<10%; Table 2), occurred in the fewest cows on mastic asphalt at the end of summer and were not related to access to pasture.

The high and low prevalence of any subclinical finding and of intermittent claw treatments (lameness), is likely to result in a numerically instable model estimation as reflected in the high cow- and farm-level variances, respectively (Table 3). These results may therefore not be fully reliable and should be interpreted cautiously.

## 4. Discussion

The aim of the present study was to investigate the effect of different well-maintained floor types in the indoor walking area of cubicle housing systems, as well as access to pasture, on claw health in dairy cows. To this end, we assessed the claws of 10 cows at each of 35 farms – 12 with solid rubber, 12 with mastic asphalt and 11 with slatted concrete floors – on three separate occasions at approx. 6-month intervals. We focused on well-maintained floors because we were not interested in the effects of the maintenance state of the floors but in the basic characteristics of the floor types. Thus, our results do not representatively reflect the current state on working farms in general but show what level of claw health can ideally be achieved on the different floor types. Little is known about the changes in the characteristics of solid rubber floor with age. It is known, though, that the quality of mastic asphalt and concrete floor changes with age and thus effects of old and less-maintained floors will result in more accentuated differences in claw health.

Farm-level variability was relatively low in this dataset (Table 3) and therefore the marginal ORs were very similar to the subject-specific ORs (Table 2). Therefore the interpretation does not depend on the choice of the type of ORs.

Floor type significantly influenced the presence of sole haemorrhages as well as slight fissures in the white line, heel horn erosion, dermatitis digitalis and the occurrence for intermittent claw trimming (taken as an indication for lameness), but not the presence of deep white line fissures and sole ulcers. Since contusions of the claw sole are often associated with hard floor surfaces (Nordlund et al., 2004; Barker et al., 2009), we expected to find fewer cows with sole haemorrhages and sole ulcers in cubicle housing systems with rubber floors similar to the findings from tie-stalls (Kujala et al., 2009). On the contrary, the presence of haemorrhages was lowest on mastic asphalt, whereas it was indeed slightly higher on slatted concrete compared to rubber flooring. The observations in respect to the mastic asphalt are consistent with those of previous studies comparing solid rubber and solid concrete floors (Boyle et al., 2007; Vanegas et al., 2006), whilst our observation in respect to slatted concrete are in line with Benz (2002), Kremer et al. (2007) and Fjeldaas et al. (2011) who found fewer sole haemorrhages in dairy cows kept on rubber-covered slatted floors than on slatted concrete floors. Mastic asphalt and slatted concrete are both hard floor surfaces, but differed in their effect on the presence of haemorrhages. This could be due to the fact that slatted concrete floors are associated with higher mechanical loads on the claws compared to solid floors (Hinterhofer

**Table 2**
Generalised mixed-effects models with binary outcomes for risk factors for different claw health risks (outcomes).

| Outcomes | Category | | Observations ($n$) | Prevalence | Subject-specific | | $p$-Value | Marginal | |
|---|---|---|---|---|---|---|---|---|---|
| Risk factor | | | | | OR | 95% CI | | OR | 95% CI |
| Haemorrhages | | | | | | | | | |
| Floor type | Rubber | | 332 | 0.56 | 1.0 | – | 0.026 | 1.0 | – |
| | Mastic asphalt | | 313 | 0.44 | 0.57 | 0.32–1.02 | | 0.59 | 0.34–1.02 |
| | Slatted concrete | | 263 | 0.63 | 1.38 | 0.76–2.54 | | 1.36 | 0.77–2.40 |
| Pasture | No | | 476 | 0.54 | 1.0 | – | 0.702 | 1.0 | – |
| | Yes | | 432 | 0.54 | 0.91 | 0.56–1.48 | | 0.91 | 0.58–1.45 |
| Season | Winter | | 396 | 0.50 | 1.0 | – | 0.021 | 1.0 | – |
| | Summer | | 512 | 0.57 | 1.43 | 1.07–1.91 | | 1.40 | 1.07–1.84 |
| Sole ulcer | | | | | | | | | |
| Floor type × season | Winter | Rubber | 139 | 0.03 | 1.0 | – | 0.031 | 1.0 | – |
| | | Mastic asphalt | 143 | 0.07 | 2.81 | 0.01–>1000 | | 1.05 | 0.80–1.38 |
| | | Slatted concrete | 114 | 0.13 | 4.18 | 0.01–>1000 | | 1.07 | 0.81–1.40 |
| | Summer | Rubber | 193 | 0.11 | 1.0 | – | | 1.0 | – |
| | | Mastic asphalt | 170 | 0.12 | 0.98 | 0.03–30.85 | | 1.00 | 0.86–1.16 |
| | | Slatted concrete | 149 | 0.10 | 1.39 | 0.04–48.64 | | 1.01 | 0.87–1.19 |
| | Rubber | Winter | 139 | 0.03 | 1.0 | – | | 1.0 | – |
| | | Summer | 193 | 0.11 | 5.13 | 1.28–20.59 | | 2.19 | 1.12–4.25 |
| | Mastic asphalt | Winter | 143 | 0.07 | 1.0 | – | | 1.0 | – |
| | | Summer | 170 | 0.12 | 3.00 | 0.95–9.46 | | 1.15 | 0.99–1.32 |
| | Slatted concrete | Winter | 114 | 0.13 | 1.0 | – | | 1.0 | – |
| | | Summer | 149 | 0.10 | 0.84 | 0.37–1.87 | | 0.84 | 0.38–1.85 |
| Pasture | No | | 476 | 0.10 | 1.0 | – | 0.501 | 1.0 | – |
| | Yes | | 432 | 0.09 | 0.80 | 0.40–1.59 | | 0.86 | 0.54–1.37 |
| Slight white-line fissures | | | | | | | | | |
| Floor type × season | Winter | Rubber | 139 | 0.83 | 1.0 | – | 0.038 | 1.0 | – |
| | | Mastic asphalt | 143 | 0.48 | 0.16 | 0.07–0.39 | | 0.18 | 0.08–0.42 |
| | | Slatted concrete | 114 | 0.73 | 0.52 | 0.20–1.35 | | 0.55 | 0.23–1.32 |
| | Summer | Rubber | 193 | 0.81 | 1.0 | – | | 1.0 | – |
| | | Mastic asphalt | 170 | 0.66 | 0.36 | 0.16–0.81 | | 0.38 | 0.18–0.82 |
| | | Slatted concrete | 149 | 0.70 | 0.41 | 0.18–0.96 | | 0.43 | 0.19–0.96 |
| | Rubber | Winter | 139 | 0.83 | 1.0 | – | | 1.0 | – |
| | | Summer | 193 | 0.81 | 1.18 | 0.19–7.32 | | 1.18 | 0.15–9.81 |
| | Mastic asphalt | Winter | 143 | 0.48 | 1.0 | – | | 1.0 | – |
| | | Summer | 170 | 0.66 | 2.51 | 0.74–7.71 | | 2.38 | 0.74–7.71 |
| | Slatted concrete | Winter | 114 | 0.73 | 1.0 | – | | 1.0 | – |
| | | Summer | 149 | 0.70 | 0.87 | 0.20–3.75 | | 0.87 | 0.22–3.52 |
| Pasture × season | Winter | Without pasture | 251 | 0.68 | 1.0 | – | 0.002 | 1.0 | – |
| | | Access to pasture | 145 | 0.66 | 0.84 | 0.40–1.75 | | 0.85 | 0.43–1.69 |
| | Summer | Without pasture | 225 | 0.84 | 1.0 | – | | 1.0 | – |
| | | Access to pasture | 287 | 0.64 | 0.30 | 0.15–0.59 | | 0.32 | 0.16–0.60 |
| | Without pasture | Winter | 251 | 0.68 | 1.0 | – | | 1.0 | – |
| | | Summer | 225 | 0.84 | 4.16 | 0.18–98.46 | | 3.87 | 0.19–78.46 |
| | Access to pasture | Winter | 145 | 0.66 | 1.0 | – | | 1.0 | – |
| | | Summer | 287 | 0.64 | 1.07 | 0.12–9.58 | | 1.07 | 0.13–8.56 |
| Deep white-line fissures | | | | | | | | | |
| Floor type | Rubber | | 332 | 0.42 | 1.0 | – | 0.133 | 1.0 | – |
| | Mastic asphalt | | 313 | 0.28 | 0.51 | 0.27–0.97 | | 0.53 | 0.29–0.97 |
| | Slatted concrete | | 263 | 0.33 | 0.63 | 0.32–1.23 | | 0.65 | 0.35–1.21 |
| Pasture | No | | 476 | 0.36 | 1.0 | – | 0.349 | 1.0 | – |
| | Yes | | 332 | 0.42 | 0.77 | 0.45–1.32 | | 0.78 | 0.47–1.30 |
| Season | Winter | | 396 | 0.31 | 1.0 | – | 0.054 | 1.0 | – |
| | Summer | | 413 | 0.46 | 1.37 | 1.01–1.86 | | 1.34 | 1.01–1.79 |
| Heel horn erosion | | | | | | | | | |
| Floor type | Rubber | | 332 | 0.67 | 1.0 | – | 0.011 | 1.0 | – |
| | Mastic asphalt | | 313 | 0.66 | 0.89 | 0.46–1.71 | | 0.90 | 0.51–1.61 |
| | Slatted concrete | | 263 | 0.49 | 0.35 | 0.18–0.70 | | 0.40 | 0.22–0.73 |
| Pasture | No | | 476 | 0.65 | 1.0 | – | 0.288 | 1.0 | – |
| | Yes | | 432 | 0.57 | 0.74 | 0.42–1.28 | | 0.76 | 0.47–1.24 |
| Season | Winter | | 396 | 0.71 | 1.0 | – | <0.001 | 1.0 | – |
| | Summer | | 512 | 0.54 | 0.42 | 0.31–0.58 | | 0.46 | 0.35–0.61 |

Table 2 (*Continued*)

| Outcomes | Category | | Observations ($n$) | Prevalence | Subject-specific | | $p$-Value | Marginal | |
|---|---|---|---|---|---|---|---|---|---|
| Risk factor | | | | | OR | 95% CI | | OR | 95% CI |
| Dermatitis digitalis | | | | | | | | | |
| Floor type × pasture | No | Rubber | 169 | 0.14 | 1.0 | – | 0.005 | 1.0 | – |
| | | Mastic asphalt | 155 | 0.08 | 0.49 | 0.13–1.78 | | 0.53 | 0.17–1.66 |
| | | Slatted concrete | 152 | 0.22 | 2.15 | 0.65–7.06 | | 1.95 | 0.69–5.55 |
| | Yes | Rubber | 163 | 0.12 | 1.0 | – | | 1.0 | – |
| | | Mastic asphalt | 158 | 0.09 | 0.70 | 0.19–2.63 | | 0.73 | 0.23–2.36 |
| | | Slatted concrete | 111 | 0.01 | 0.06 | 0.01–0.96 | | 0.09 | 0.01–0.96 |
| | Rubber | No | 169 | 0.14 | 1.0 | – | | 1.0 | – |
| | | Yes | 163 | 0.12 | 0.67 | 0.18–2.52 | | 0.73 | 0.26–2.07 |
| | Mastic asphalt | No | 155 | 0.08 | 1.0 | – | | 1.0 | – |
| | | Yes | 158 | 0.09 | 1.01 | 0.30–3.43 | | 1.01 | 0.32–3.24 |
| | Slatted concrete | No | 152 | 0.22 | 1.0 | – | | 1.0 | – |
| | | Yes | 111 | 0.01 | 0.02 | 0.00–0.35 | | 0.04 | 0.00–0.41 |
| Season | Winter | | 396 | 0.11 | 1.0 | – | 0.270 | 1.0 | – |
| | Summer | | 512 | 0.12 | 1.31 | 0.81–2.10 | | 1.27 | 0.83–1.93 |
| Occurrence of any of the subclinical findings | | | | | | | | | |
| Floor type | Rubber | | 332 | 0.98 | 1.0 | – | 0.363 | 1.0 | – |
| | Mastic asphalt | | 313 | 0.91 | 0.26 | 0.00–38.42 | | 0.95 | 0.78–1.16 |
| | Slatted concrete | | 263 | 0.93 | 0.31 | 0.00–53.57 | | 0.95 | 0.77–1.17 |
| Pasture × season | No | Winter | 251 | 0.94 | 1.0 | – | 0.015 | 1.0 | – |
| | | Summer | 225 | 0.96 | 2.24 | 0.63–8.02 | | 1.04 | 0.89–1.64 |
| | Yes | Winter | 145 | 0.96 | 1.0 | – | | 1.0 | – |
| | | Summer | 287 | 0.92 | 0.23 | 0.06–0.92 | | 0.95 | 0.80–0.99 |
| | Winter | No | 251 | 0.94 | 1.0 | – | | 1.0 | – |
| | | Yes | 145 | 0.96 | 1.93 | 0.01–352.63 | | 1.03 | 0.82–1.29 |
| | Summer | No | 225 | 0.96 | 1.0 | – | | 1.0 | – |
| | | Yes | 287 | 0.92 | 0.72 | 0.01–45.79 | | 0.99 | 0.82–1.18 |
| Intermittent claw treatment (lameness) | | | | | | | | | |
| Floor type × season | Winter | Rubber | 139 | 0.09 | 1.0 | | <0.001 | 1.0 | |
| | | Mastic asphalt | 143 | 0.10 | 1.08 | 0.06–18.12 | | 1.02 | 0.52–2.00 |
| | | Slatted concrete | 114 | 0.07 | 0.57 | 0.03–12.42 | | 0.88 | 0.42–1.82 |
| | Summer | Rubber | 193 | 0.09 | 1.0 | – | | 1.0 | – |
| | | Mastic asphalt | 170 | 0.02 | 0.11 | 0.00–79.54 | | 0.90 | 0.67–1.22 |
| | | Slatted concrete | 149 | 0.05 | 0.42 | 0.01–33.43 | | 0.96 | 0.78–1.18 |
| | Rubber | Winter | 139 | 0.09 | 1.0 | – | | 1.0 | – |
| | | Summer | 193 | 0.09 | 1.59 | 0.68–3.70 | | 1.51 | 0.71–3.19 |
| | Mastic asphalt | Winter | 143 | 0.10 | 1.0 | – | | 1.0 | – |
| | | Summer | 170 | 0.02 | 0.05 | 0.01–0.27 | | 0.32 | 0.17–0.61 |
| | Slatted concrete | Winter | 114 | 0.07 | 1.0 | – | | 1.0 | – |
| | summer | | 149 | 0.05 | 0.80 | 0.25–2.56 | | 0.91 | 0.55–1.50 |
| Pasture | No | | 476 | 0.07 | 1.0 | – | 0.820 | 1.0 | – |
| | Yes | | 432 | 0.06 | 0.86 | 0.24–3.13 | | 0.92 | 0.43–1.97 |

et al., 2006). As far as sole ulcers were concerned, the pattern in their presence was similar to our hypothesis, but with a wide confidence interval.

**Table 3**
Variance components of the generalised mixed-effects models shown in Table 2 given as an estimated variance ± SE of the different levels of random effects.

| Outcomes | Variance components | |
|---|---|---|
| Risk factor | Farm-level variability | Cow-level variability |
| Haemorrhages | 0.30 ± 0.55 | 0.53 ± 0.73 |
| Sole ulcer | 0.12 ± 0.35 | 1.82 ± 1.35 |
| Slight white-line fissures | 0.57 ± 0.75 | 0.23 ± 0.48 |
| Deep white-line fissures | 0.40 ± 0.63 | 0.45 ± 0.67 |
| Heel horn erosion | 0.38 ± 0.62 | 0.80 ± 0.90 |
| Dermatitis digitalis | 0.70 ± 0.84 | 0.56 ± 0.75 |
| Occurrence of any of the subclinical findings | 0.00 ± 0.00 | 42.25 ± 6.50 |
| Intermittent claw treatment (lameness) | 2.31 ± 1.52 | 0.00 ± 0.00 |

Slight white-line fissures occurred less frequently in cows kept on mastic asphalt and slatted concrete floors than on rubber floors and was rarest in winter on mastic asphalt. Mastic asphalt is known to be an abrasive floor type that wears away much of the claw horn (Telezhenko, 2007); slatted concrete flooring, too, is more abrasive than rubber flooring (Kremer et al., 2007; Platz et al., 2007). Abrasion is likely to result in increased wear of the white line; consequently, slight white-line fissures may no longer be visible after several months of exposure to a hard floor types. By contrast, cows on a soft rubber floor usually have a concave claw sole with a protruding claw wall and less claw-horn wear (Benz, 2002), aiding in the identification of slight white-line fissures. Contrarily, white-line disease was more rarely found on softer floors in tie-stalls (Kujala et al., 2010) and free-stalls (Fjeldaas et al., 2011). In the present study, the presence of deep fissures was not significantly associated with floor type. Possibly, slight white-line fissures are subject to so much wear on the hard floors that they are prevented from developing into deep white-line fissures whereas they do not develop on the rubber floor at all.

Heel-horn erosions occurred with the lowest frequency in cows kept on slatted concrete floors. One possible reason is that slatted floors drain liquid manure faster than solid floors, with the result that cows' claws may be less exposed to manure and urine. In keeping with our results, Thysen (1987) found fewer cows with heel-horn erosions on slatted floors than on solid floors and Kremer et al. (2007) reported a greater incidence of heel-horn erosions on a rubber-covered slatted floor than on a slatted concrete floor. On the contrary, Vanegas et al. (2006) reported a higher presence of heel-horn erosions in cows kept on a solid concrete floor than on a solid rubber floor.

Dermatitis digitalis was generally on a lower level in our study compared to others (e.g. Somers et al., 2003) and we could not observe systematic differences between floor types. The same can be said for intermittent claw trimming, as the number of cows needing such treatment was lowest in summer but only on mastic asphalt.

Access to pasture had little beneficial effects on the cows in that dermatitis digitalis was reduced (on slatted concrete) and slight white-line fissures occurred more rarely when access to pasture was provided. The latter effect was independent of the floor type and was also found for the risk of any of the subclinical findings. As dermatitis digitalis was quite common, it is likely that these same patterns are reflected in the risk of any of the subclinical findings. As the cows on the farms with access to pasture were found in smaller herds, yielded less milk, had concurrent access to an outdoor run and had a hay based diet more often (Table 1), that positive effect might be partly attributed to these other aspects. By contrast, access to pasture did not significantly reduce the presence of sole haemorrhages, sole ulcers or heel-horn erosions. This was in contrast to the results of Somers et al. (2003) in a study comparing claw health in cows with and without access to pasture, mainly on farms with slatted concrete floors. Similarly, Hernandez-Mendo et al. (2007) reported a lower lameness rate in cows kept continuously at pasture than in those kept on solid concrete floors. The cows of the present study spent a relatively short time at pasture compared to those studied by Somers et al. (2003) and Hernandez-Mendo et al. (2007) – probably too short a time to exert a positive effect on these types of claw lesions. Alternatively, co-varying aspects such as herd size, milk yield, access to an outdoor run and diet composition might have nullified any beneficial effect of the use of pasture, but this seems unlikely, as these effects would rather be expected to reduce subclinical claw findings as described above.

Season, i.e. the period before claw trimming, influenced the presence of sole haemorrhages (more likely in summer), sole ulcers (more likely in summer on rubber and mastic asphalt), deep white-line fissures (a tendency for being more likely in summer), and heel-horn erosions (less likely in summer) independent of access to pasture. This is in line with the studies of Cook et al. (2006) and Sanders et al. (2009), who also found that cows had a higher risk of sole haemorrhages at the end of the summer period than at the end of the winter period. Heat stress (Stone, 2004; Cook et al., 2007) and nutritional changes (Cook and Nordlund, 2009) could be responsible for such a negative effects on claw haemorrhages. By contrast, higher temperatures in summer may accelerated drying of the floor surface in the walking areas of the cubicle housing systems, thereby reducing claw exposure to manure and urine and thus reducing heel-horn erosion. Somers et al. (2003) found no seasonal differences in the presence of heel-horn erosions in zero-grazed cows, though.

## 5. Conclusions

In conclusion, the effect of floor type on claw health was slight. None of the floor types investigated was clearly superior to the others in terms of its effect on claw health. The hypothesis that soft rubber flooring could in general reduce claw lesions was not supported. Also, access to pasture during summer had only a slight influence on the claw-health parameters investigated. Our hypothesis that limited access to pasture as provided by the farms studied would mitigate the negative effects of the floor types, especially with respect to sole haemorrhages, sole ulcers and heel-horn erosions, was therefore not corroborated.

## Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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