Hock lesion epidemiology in cubicle housed dairy cows across two breeds, farming systems and countries

Christine Brenninkmeyer a,⁎, Sabine Dippel b,1, Jan Brinkmann c,2, Solveig March c,2, Christoph Winckler b, Ute Knierim a

a Farm Animal Behaviour and Husbandry Section, University of Kassel, Nordbahnhofstraße 1a, 37213 Witzenhausen, Germany
b Division of Livestock Sciences, Department of Sustainable Agricultural Systems, University of Natural Resources and Life Sciences, Gregor-Mendel Straße 33, 1180 Vienna, Austria
c Department of Animal Sciences, Faculty of Agricultural Sciences, Georg-August-University of Goettingen, Location Vechta, Driverstrasse 22, 49377 Vechta, Germany

A R T I C L E   I N F O

Article history:
Received 2 September 2011
Received in revised form 19 October 2012
Accepted 23 October 2012

Keywords:
Swelling
Injury
Lameness
Dairy cattle
Free-stalls
Animal welfare
Simmental

A B S T R A C T

This cross-sectional study examined various aspects of cubicle design and management in terms of their potential as risk factors for hock lesions, using an epidemiological approach. Cubicle dairy farms in Germany and Austria with Holstein Friesian or Simmental cows were visited during the winter housing season. 105 farms and 3691 cows were included in the analysis which consisted of three steps: bifactorial regression, regression trees and multiple linear regression. The mean farm prevalence of hock lesions, i.e. scabs, wounds, and swellings was 50%, with a range from 0 to 100%. The final model contained eight factors which were largely related to lying comfort and explained 75% of the variance. The presence of a curb turned out to be the most influential beneficial factor. Additionally, there were fewer hock lesions when cows were housed with deep bedded cubicles compared to cubicles without deep bedding. Other factors in the regression model were softness and length of the lying surface and height of free space under cubicle partitions, the proportion of overconditioned cows and a variable encoding three different combinations of region, husbandry system (organic and conventional) and breed. Independently from the risk factor model hock lesions were positively correlated with lameness at herd level as well as at animal level. This probably results from related risk factors for both conditions. It can be concluded that lying comfort of dairy cows should be improved in order to prevent hock lesions. In addition, preventive measures for hock lesions at the same time have a potential of reducing lameness and thus to improve cow welfare in several aspects.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

High prevalence of hock lesions (HL) is a common finding in dairy herds in cubicle housing (e.g. Weary and Taszkun, 2000: 73%; Kielland et al., 2009: 61% of all hind legs). In the case of severe swellings or suppurative wounds, these lesions may be a risk factor for lameness (Klaas et al., 2003). However, HLS are also of concern for cow welfare as in general they are associated with pain and also with an increased risk of spreading pathogens (Livesey et al., 2002). Additionally, HLS may be an indicator
of repeated physical conflicts between the animals and their housing environment. Prevalence of crusts on the tarsal joints has been shown to be linked with increased adrenocortical activity (Rouha-Müller et al., 2010). This may indicate that the physical conflicts and the associated reductions of freedom to express normal resting behaviour cause discomfort to the animals. In a survey by Angus et al. (2005) 56 dairy cow welfare experts, practising veterinary surgeons and veterinary students rated the importance of factors affecting dairy cow welfare, based on their own experience and knowledge. The presence of HL was ranked highest of nine factors in the category “freedom from discomfort”.

HL may be caused by prolonged high local pressure on hard surfaces or edges or by abrasive lying surfaces. In line with this the quality of the lying area in terms of softness and friction was found to be associated with number and severity of HL in epidemiological studies (Rodenburg et al., 1994; Wechsler et al., 2000; Weary and Taszkun, 2000; Kögl et al., 2003; Keil et al., 2006; Rutherford et al., 2008; Lombard et al., 2010; Potterton et al., 2011) as well as under experimental conditions (Vokey et al., 2001; Livesey et al., 2002; Mowbray et al., 2003). However, results are not quite consistent regarding the relative effect of softness and kind and amount of bedding (Chaplin et al., 2000). Another potential cause of HL are collisions of the cows with cubicle fittings due to inadequate cubicle design and dimensions, especially in relation to the size of the cows (Zerrawy, 1989; Bockisch, 1991; Haskell et al., 2006; for tie-stall systems: Keil et al., 2006). Access to pasture has been found to have a beneficial effect (Rutherford et al., 2008) as well as duration of outdoor exercise for tied cows (Keil et al., 2006). Additionally, there may be animal-related risk factors such as body condition, with a reduced risk of HL with increasing body condition score (BCS; Kielland et al., 2009; Potterton et al., 2011).

Interactions between factors which will likely have an effect on HL, e.g. dimensions of the lying area and other cubicle properties, have not been well investigated yet (Keil et al., 2006). Regarding interacting cubicle characteristics, animal-based measures related to rising or lying down may pose an integrated measure. For example, Potterton et al. (2011) found that slipping while rising was associated with an about eightfold increased risk for hock swellings and having contact with fittings while rising nearly doubled the risk.

Further potentially influencing factors deserving better investigation include human–animal relationship, or several management factors such as the use of lime as hygienic product in cubicles, the housing of dry cows or cow cleanliness. The latter might have an ambiguous relationship with HL, as a dirt coating of the hock might have a protective effect (Potterton et al., 2011) as well as at the same time increase abrasion, particularly on rubber mats. Cleanliness may furthermore serve as systematic indicator for general hygienic conditions.

Therefore, the objective of this epidemiological study was to identify and evaluate major risk factors for HL, including animal based measures, in cubicle housed organic and non-organic dairy herds of two different breeds in a comparably large data set of 105 dairy farms in Germany and Austria. In addition, it was the aim to quantify potential associations between HL and lameness.

2. Animals, material and methods

2.1. Sample

Farms were searched with help of the milk inspection boards and were required to have cubicle housing of Holstein Friesian or Simmental cows and twice a day milking in a milking parlour. For practical reasons we only chose farms equipped with head lockers. We excluded farms with turnout of cows for alpine grazing, rubber flooring in the alleys and acute outbreak of diseases to reduce confounding. We tried to balance samples with regards to cubicle type (deep bedding vs. cubicles with raised cubicle base), flooring type in the alleys (solid vs. slatted flooring), and the presence or absence of outdoor loafing areas. Farms had to be in use with the current fittings for at least one year. During farm visits it turned out that three farms had made alterations in their barns less than one year ago, one regarding cubicle dimensions six months ago, one relating to the feed rack eight months ago, and the last with respect to drinkers 11 months ago. In all three cases the time between the changes and the farm visits was judged long enough to allow for the effects of the altered equipment to show in the animal based parameters and thus the farms were included in analysis. We originally aimed for a pre-defined range of mean yearly milk yield (7000–10,000 kg fat-protein-corrected yield) and cow:cubicle ratio (0.85–1.15) in the sample to reduce variance in these potential confounders but those limits could not be kept due to lack of choice. In the final data set, milk yield ranged from 5276 to 10,360 with a mean of 8048 and cow:cubicle ratio ranged from 0.62 to 1.57 with a mean of 0.98.

The data set comprised 105 farms. It consisted of three sub-data sets: sub-data set “A” collected by observer “a” on 34 farms in Austria, sub-data set “B” comprising 38 organic farms distributed all over Germany, collected by two observers (“b” and “c”) together and sub-data set “D” collected by observer “d” on 33 farms in central Germany.

All 34 A-farms kept Simmental cows only, as it was not possible to find a sufficient set of farms with Holstein Friesian cows in Austria; they were all located in non-alpine regions. The 38 B-farms were solely organic farms keeping Holstein Friesian cows, and were distributed across Germany. The 33 D-farms were all located in central Germany and kept Holstein Friesian cows. The 105 farms kept on average 58 cows in their milking herds, with an overall mean fat-protein-corrected milk yield of 8048 kg (Table 1). Further details on housing and management conditions are presented in Table 1.

2.2. Data collection

Based on literature and own experience a list of potential risk factors for HL was compiled that also considered possible interactions between factor pairs (Tables 2 and 3). Lying down duration was included as an integrative animal-based measure of the interaction between all cubicule characteristics and the body dimensions of the cows.
Further animal-based measures were body condition score, human–animal relationship and proportion of dirty cows. Farm visits took place during the winter housing season 2004/05. Data collection included direct observations during one afternoon, evening and the consecutive morning, and an inventory of housing conditions. Management data were collected in a 1–1.5 h questionnaire guided interview with the farmer.

With respect to data on housing conditions there was considerable within farm variation of cubicle

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Category/measurement</th>
<th>A N = 34</th>
<th>B N = 38</th>
<th>C N = 33</th>
<th>D N = 105</th>
<th>All N [%]</th>
<th>All [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm type</td>
<td>Non-organic farms</td>
<td>31</td>
<td>0</td>
<td>32</td>
<td>64</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Organic farms</td>
<td>3</td>
<td>38</td>
<td>1</td>
<td>41</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Fat-protein-corrected yield</td>
<td>Max</td>
<td>10,117</td>
<td>9363</td>
<td>10,360</td>
<td>10,360</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>8276</td>
<td>7157</td>
<td>8839</td>
<td>8048</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>6133</td>
<td>5276</td>
<td>7495</td>
<td>5276</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size</td>
<td>Max</td>
<td>103</td>
<td>156</td>
<td>99</td>
<td>156</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>40</td>
<td>69</td>
<td>63</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>28</td>
<td>34</td>
<td>32</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor loafing area</td>
<td>Farms without outdoor loafing area</td>
<td>18</td>
<td>25</td>
<td>30</td>
<td>73</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farms with outdoor loafing area</td>
<td>16</td>
<td>13</td>
<td>3</td>
<td>32</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Cubicle type</td>
<td>Farms with deep bedded cubicles</td>
<td>23</td>
<td>15</td>
<td>17</td>
<td>55</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farms with bedded cubicles (but no deep bedding)</td>
<td>4</td>
<td>18</td>
<td>8</td>
<td>30</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farms with cubicles without bedding</td>
<td>7</td>
<td>5</td>
<td>8</td>
<td>20</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Softness of rear part of cubicle floor [1 = hard, 2 = medium, 3 = soft]</td>
<td>% Score 1</td>
<td>50</td>
<td>24</td>
<td>24</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>% Score 2</td>
<td>44</td>
<td>31</td>
<td>55</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free space under cubicle partitions [cm]</td>
<td>Max</td>
<td>86</td>
<td>99</td>
<td>78</td>
<td>99</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>53</td>
<td>52</td>
<td>51</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>41</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of the lying area [cm]</td>
<td>Max</td>
<td>214</td>
<td>213</td>
<td>216</td>
<td>216</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>186</td>
<td>196</td>
<td>222</td>
<td>196</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>152</td>
<td>157</td>
<td>155</td>
<td>152</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion of cows with BCS ≥ 4.00 [%]</td>
<td>Max</td>
<td>90</td>
<td>57</td>
<td>21</td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>55</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A = Austrian farms with Simmental cows assessed by observer a; B = German organic farms with Holstein Frisian cows assessed by observers b and c together; D = Central German farms with Holstein Frisian cows assessed by observer d.

Table 2

Statistically examined potential risk factors for prevalence of hock lesions related to lying.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubicle length</td>
<td>Length from inner part of curb/functional end of mattress to middle of head-to-head cubicles, or wall respectively</td>
</tr>
<tr>
<td>Cubicle width</td>
<td>Clear width from inner side of partition to inner side of partition</td>
</tr>
<tr>
<td>Length of lying area</td>
<td>Distance between curb/hind end of cubicle and brisket board, or cubicle length minus 40 cm for face-to-face cubicles/60 cm for wall facing cubicles if no brisket board present or brisket board closer to front end than the respective value (40 or 60 cm)</td>
</tr>
<tr>
<td>Too short neck rail-curb diagonal</td>
<td>1 = diagonal between end of bed/inner side of curb and neck rail too small (&lt;193 cm for HF, &lt;190 for Simmental); 0 = no neck rail or neck rail curb diagonals long enough</td>
</tr>
<tr>
<td>Free space under cubicle partitions</td>
<td>Clear height between bedding and lowest horizontal part of cubicle partition, measured at 75 cm from rear end of lying area</td>
</tr>
<tr>
<td>Presence of head lunge obstacles</td>
<td>1 = rail etc. of some sort restricting head lunge in at least one cubicle measured; 0 = no head lunge restricting fittings*</td>
</tr>
<tr>
<td>Presence of a curb</td>
<td>1 = cubicles with curb; 0 = cubicles without curb</td>
</tr>
<tr>
<td>No deep bedded cubicle</td>
<td>1 = straw-/straw-dung mattress in cubicles; 0 = deep bedding consisting of straw-/straw-dung mattress in cubicles</td>
</tr>
<tr>
<td>Softness of rear part of lying area</td>
<td>Farm median of softness scores in rear part of cubicles; 1 = hard = &quot;like concrete or wooden boards: you don't drop on your knees voluntarily&quot;, 2 = medium = &quot;like camping mat made from rubber foam; unpleasant when dropping with versel&quot;; 3 = soft = &quot;like mattress/a 10 cm layer of sawdust; painless/soft landing&quot;</td>
</tr>
<tr>
<td>Height of loose bedding material in rear of cubicle</td>
<td>Height of bedding material on rear part of cubicle; if straw/dung mattress: loose bedding material on top, only</td>
</tr>
<tr>
<td>Risk of splints in bedding</td>
<td>1 = saw dust/wood shavings used for bedding (even if mixed with straw); 0 = no saw dust/wood shavings in cubicles</td>
</tr>
<tr>
<td>Use of lime in cubicles</td>
<td>1 = lime powder used in cubicles; 0 = no lime powder used in cubicles</td>
</tr>
<tr>
<td>Time of lying down</td>
<td>Farm median of all recorded lying down events</td>
</tr>
<tr>
<td>Cow:cubicle-ratio</td>
<td>Number of cows in milking herd divided by accessible cubicles</td>
</tr>
</tbody>
</table>

* Calculations based on 90% percentiles of body measures of 295 Simmental and 364 Holstein cows on 20 farms in sub-data set A and D as described by Dippel et al. (2009).
measurements and fittings on some farms. Depending on cubicle heterogeneity, 1–12 wall facing and 2–12 face-to-face cubicles were assessed. Weighted mean values (for proportion of wall facing/face-to-face cubicles) were then calculated, except for the neck rail to curb diagonal which was classified as fulfilling or not fulfilling minimum recommendations (see Table 2). The duration of at least 6 lying down movements from first contact of one carpal joint with the ground to full body contact with the ground was recorded using a stopwatch.

Animal-based measures (lesions, body condition score, dirtiness and gait) were scored from a random sample of at least 30 (unless there were fewer cows in the milking herd) to 50 cows. The number of samples taken per farm was sufficient to estimate a within-herd prevalence of 0.5 with 0.1 precision and a confidence level of 0.9.

Cows were selected by marking cows in predefined random positions on the list of cows in milk at the time of farm visit if available, or alternatively by choosing/missing every xth cow in the parlour or feed rack. Non-lactating cows, cows from a breed other than Holstein Friesian or Simmental, as well as cows in sick pens were excluded.

For dirtiness scoring we used the system of Faye and Barnouin (1985) which includes four body regions (rear view of the cow including rear view of the udder, hind leg lateral from above the hock to hip bone and seat bone, udder: lateral and ventral view, flank: lateral and ventral view) and ranks on a five score scale (from 0 = clean to 4 = very dirty).

At the end of the farm visit, the reactivity of the cows in the herd towards humans was subjectively assessed using three categories (Table 3).

2.3. Hock lesions and lameness

The hock region was defined as the lateral and medial tarsus as well as the lateral, medial and dorsal calcaneus. Both hind legs of an animal were examined, resulting in ten areas in the hock region per animal. It was inspected by adspecctation and palpation while the cow was fixed in the feed rack.

HL included scabs, wounds and swellings of any size and severity. Gait scoring was performed as described by Winckler and Willen (2001) on a five score scale with scores 1 and 2 representing normal locomotion and scores 3–5 representing lame animals.

2.4. Observer agreement

All four observers met before and at the end of the study in order to test the inter-observer reliability (IOR) for BCS, gait and HL scoring at animal level on ten (all four observers) to 14 (observers a and d) farms. For HL scoring, the left rear leg of 21 cows before and 48–69 cows after data collection was examined independently by each observer. The same cows were scored for BCS. For gait, 135–150 cows were scored before and 50–144 cows after data collection. PABAK (Prevalence Adjusted Bias Adjusted Kappa: Byrt et al., 1993; Abramson, 2003) was calculated for each observer pair for HL and gait before and after data collection. Following the classifications of Fleiss et al. (2003) for kappa-values we interpreted PABAK ≥ 0.75 as excellent, between 0.4 and 0.75 as fair to good and <0.4 as poor agreement. Spearman Rho was calculated for body condition scores. The limit of acceptability was set at 0.70 (Martin and Bateson, 2007).

HL IOR was excellent in two (= 17%; PABAK-values = 0.77 and 0.81), fair to good in nine (= 75%; PABAK-values from 0.43 to 0.62) and poor in one (= 8%; PABAK = 0.33) of all tests. The single poor PABAK resulted from observer pair b and c before data collection. They consequently examined cows together during data collection. IOR of observers b and c after data collection was good (PABAK = 0.58). IOR for gait was excellent in 25% and fair to good in 75% of all tests (see also Brenninkmeyer et al., 2007). Spearman Rhos for
BCS all passed the acceptability limit, ranging from 0.74 to 0.91.

2.5. Statistical methods

HL data was analysed on herd level using within herd prevalence as dependent variable. All statistical analyses for HL models were adjusted for possible effects deriving from different distributions of characteristics in the three sub-datasets, namely cattle breed, observer identity, region/country and farming type, i.e. organic or conventional farming by including sub-dataset as a factor. In the case of factor screening using regression trees separate analyses were carried out for the sub-datasets as well (see below).

Interactions between selected potential risk factors were calculated using the following procedure: Continuous variables where risk was expected to increase with decreasing value were reversed by subtracting the values from the maximum variable value plus 1. All factors were then standardised to a mean of 0.5 with a standard deviation of 0.16667, resulting in an approximate range of 0–1. Dichotomous factors had already been defined to be 0 or 1, with 1 representing the expected higher risk. Finally, the factors were multiplied to form an interaction variable. According to this, interactions of dichotomous variables were also dichotomous, with 1 representing the combination of both risks and 0 for all other combinations. Interaction variables were treated like other variables during the remainder of the process. Variables where one category was represented by less than 20% of the sample were not considered for variable selection, which resulted in only two interactions to be included in the modelling process.

Variable selection from the list of potential risk factors consisted of three steps (modification of the modelling process proposed by Dahms, 2004).

Step 1 (\(\text{step}\)): Avoidance of strong correlations between factor variables.

Scatter plots with density ellipses (ellipse alpha = 0.95) were created for all independent variables (JMPIN 5.1.2, “multivariate” function), and visually inspected with regard to correlation strength. Relations between dichotomous variables were surveyed using mosaic plots. Spearman Rho with absolute values of \(\rho \geq 0.6\) for continuous variables, and absolute Kappa-values > 0.4 for pairs of dichotomous variables were used as additional indicators for correlations between variables. Closely related variables with obvious redundancy of information were merged or the one with more missing values or lower data quality (e.g. ordinal compared to continuous), or the more uneven distribution was excluded.

Step 2 (\(\text{step}\)): Screening for factors of influence.

Two procedures were run in parallel:

Step 2a (\(\text{step}\)): Bifactorial screening.

For each independent variable that had passed selection step 1, a regression model including a 3-levelled categorical variable correcting for possible effects of sub-datasets was calculated (PROC GLM, SAS 9.1.3 for Windows). Variables with a \(p\)-value below 0.25 were carried over to selection step 3.

Step 2b (\(\text{step}\)): Regression trees.

Regression trees were calculated for the entire data set and additionally for each sub-data set separately (“partition”-function in JMPIN 5.1.2), resulting in four regression trees. All independent variables which had passed selection step 1 were used. The smallest branches of the trees were based on at least five farms or a minimum partial \(R^2\) of 0.01. All variables contributing to at least one regression tree were carried over to selection step 3.

Step 3 (\(\text{step}\)): Multiple linear regression with forward stepwise and backwards selection.

All variables which had passed the first two selection steps were offered to a forward stepwise selection and a backwards selection in a multiple linear regression model (PROC REG, SAS 9.1.3 for Windows). Variables were to be entered if their \(p\)-value was smaller than 0.5 (for forward stepwise, only) and kept in the model if their \(p\)-value did not exceed 0.2. Factors with \(p\)-values between 0.05 and 0.2 were kept in the model if they contributed to the adjusted \(R^2\)-value. In order to adjust for sub-dataset effects, the encoding 3-levelled variable had to be re-coded as two dichotomous variables with the values 0 and 1. The data set with the lowest prevalence values \((B)\) was chosen as the intercept.

Validity of the final models was evaluated by taking into account \(R^2\), adjusted \(R^2\), model \(p\)-value and \(p\)-values of included factors, as well as independency of factor variables as assessed by variance inflation factor (VIF) statistics. Factors with VIF < 10 were considered to indicate no multicollinearity between factors (Bühner and Ziegler, 2009). Furthermore, the assumptions of homoscedasticity and normal distribution of the residuals were tested graphically. Stability of the modelling process was evaluated by comparing the models resulting from both selection methods (forward stepwise and backwards).

In order to detect possible associations between HL and lameness, a chi-square test was calculated at animal level. On herd level, Pearson Rho was calculated between herd prevalence values of HL and lameness (both: PROC FREQ, SAS 9.1.3 for Windows). Two out of 105 farms used for HL modelling could not be included in this analysis due to missing lameness values, resulting in a sample size of 103.

3. Results

3.1. Distribution of hock lesions

Herd prevalences of HL ranged from 0 to 100% with a mean of 50\% (Table 4). Scabs or wounds had a mean herd prevalence of 36\% (range 0–97\%). The same mean prevalence was found for swellings in the hock region, with a range from 0 to 100\%. At animal level, 22\% of the examined cows had both types of alteration in the hock region at the same time. 38\% of all examined cows had lesions (scabs/wounds and/or swellings) at the tarsal joint and 29\%
had lesions at the calcaneus; partly both locations were affected (19% of all animals).

3.2. Multiple linear regression model for hock lesions

Out of the 19 independent factors and 2 interactions offered for selection (Tables 1 and 2), six factors passed selection steps 1 and 2 and were thus included in the final model in addition to the two factors coding for the sub-datasets. Backwards selection and stepwise forward selection resulted in the same model (Table 5).

The model explained 75% of the variance and had a p < 0.0001 (F = 35.66). Visual inspection of residuals indicated that the preconditions of normal distribution and homogeneity of variance were fulfilled. VIFs were all <10, indicating no multicollinearity between factors.

All but one significant factor in the final model were related to cubicule design. The presence or absence of a curb was the most influential factor. 71 (68%) of the 105 farms had cubicles with curbs. The presence of the curb accounted for about 21% less cows with HL (Table 5). Out of the 71 farms with cubicles with curbs, 55 had deep bedded cubicules, which had an additional beneficial effect: farms with deep bedded cubicules had on average 19% less cows with HL.

Another three factors included in the model were also related to cubicule design. Lower HL prevalence was found on farms with soft lying surfaces (−17.2% for soft versus hard), longer lying areas (−3.0% per 10 cm) and more space under the cubicule divisions (−3.9% per 10 cm). The prevalence of HL tended to be higher for herds with more overconditioned cows (+2.5% per 10% more cows with body condition score ≥4) but the 95% confidence interval for this estimate includes 0.

3.3. Relation between lameness and hock lesions

Absence of lesions was positively associated with normal locomotion (Chi-square = 115, N = 3513 cows, p < 0.0001). Also at herd level there was a moderate, highly significant positive correlation between HL prevalence and lameness prevalence (Pearson Rho = 0.48, N = 103 farms, p < 0.0001).

4. Discussion

4.1. Prevalence levels of hock lesions

As the main focus of the study was the identification of risk factors rather than the exact quantification of the current state of hock health, potential bias on HL prevalence as a side effect of farm selection criteria was accepted. However, the mean HL prevalence of 50% is comparable to other studies in Europe (Kögler et al., 2003; Veissier et al., 2004; Rutherford et al., 2008; Kielland et al., 2009; Rouha-Müller et al., 2010) as well as in North America (Rodenburg et al., 1994; Weary and Taszkun, 2000; Fulwider et al., 2007), although contrary to our study, hairless areas were considered as hock lesions in most other studies (except Weary and Taszkun, 2000; Veissier et al., 2004) and these often contributed most to the prevalence values. Thus, prevalence of scabs and swellings is reported to be much lower in some studies (0–17% for swellings, depending on cubicule base: Fulwider et al., 2007; 6% for wounds and 1% for swellings: Kielland et al., 2009). This might be due to the fact that we were able to identify even mild swellings and very small scabs, because palpation was routinely performed (in contrast to all other studies cited except Müller and Waiblinger, 2004; Rouha-Müller et al., 2010) and very close visual inspection was possible due to fixing the animal in headlockers during the examination. Additionally, headlamps in case of darker feed alleys were used. On the other hand, the mean prevalence of hock swellings found by Potterton et al. (2011) with visual inspection only, was 100% in a sample of 63 herds with cubicule housing in UK when including the least severe category ("hock thicker than normal"), and 25.3% for moderate ("hock is obviously swollen") or severe ("hock is

Table 5

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Standard error</th>
<th>p &gt;</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.1976</td>
<td>0.3037</td>
<td>0.5947</td>
<td>1.8005</td>
</tr>
<tr>
<td>Correction for sub-dataset A</td>
<td>0.2722</td>
<td>0.0874</td>
<td>0.0024</td>
<td>0.0986</td>
</tr>
<tr>
<td>Correction for sub-dataset D</td>
<td>0.4137</td>
<td>0.0444</td>
<td>&lt;0.0001</td>
<td>0.3257</td>
</tr>
<tr>
<td>Presence of a curb [0/1]</td>
<td>−0.2116</td>
<td>0.0586</td>
<td>0.0050</td>
<td>−0.3279</td>
</tr>
<tr>
<td>No deep bedding in cubicules [0/1]</td>
<td>0.1882</td>
<td>0.0565</td>
<td>0.0012</td>
<td>0.0760</td>
</tr>
<tr>
<td>Softness of rear part of lying area [1 = hard, 2 = medium, 3 = soft]</td>
<td>−0.0859</td>
<td>0.0257</td>
<td>0.0012</td>
<td>−0.1369</td>
</tr>
<tr>
<td>Free space under cubicule partitions [cm]</td>
<td>0.0039</td>
<td>0.0019</td>
<td>0.0433</td>
<td>−0.0077</td>
</tr>
<tr>
<td>Length of the lying area [cm]</td>
<td>0.0030</td>
<td>0.0015</td>
<td>0.0500</td>
<td>−0.0060</td>
</tr>
<tr>
<td>Proportion of cows with a body condition score ≥4</td>
<td>0.2510</td>
<td>0.1507</td>
<td>0.0992</td>
<td>0.0483</td>
</tr>
</tbody>
</table>

TABLE 5

Outcome of the final linear regression model for hock lesion prevalence based on 105 dairy farms in Germany and Austria with the main breeds Holstein Friesian and Simmental, respectively.
on the hock for Holstein breeds compared to non-Holstein breeds, but this effect did not show up for ulcerations and swellings.

All other factors identified in our model support the underlying hypotheses how HL are caused. Mainly three different mechanisms can be presupposed:

- Abrasion on rough or hard surfaces or rubber surfaces (e.g. Haskell et al., 2006);
- Impeded blood circulation in areas of the limb and body exposed to prolonged high pressure due to high body weight and non-elastic lying surface (e.g. Kaltenböck, 1972, cited from Zerzawy, 1989);
- Collision with cubicle partitions and lying surface in the course of lying down and standing up (e.g. Haskell et al., 2006).

As we assumed that these mechanisms are the same in organic and conventional farming, different regions and breeds, we did not calculate interactions with the variables encoding the sub-datasets. If this assumption would be wrong, factors affecting only a certain breed, farming system or region would be underestimated due to the effect of averaging. On the other hand, it was a goal of this study, to identify factors which are important in a more general sense.

Absence of a curb and of deep bedding together accounted for an increase in lesion prevalence of approximately 40%. Reasons for the positive effect of the presence of a curb and deep bedded cubicles are likely due to the positive effect of bedding: the curb is installed to keep the bedding inside the cubicle, thus, cubicles with a curb usually contain more bedding material, especially in the rear part, than cubicles without curb. For deep bedded cubicles this is even more the case. The bedding prevents abrasion and allows for sufficient blood circulation due to softness and elasticity of the lying surface. This conforms to results from Wechsler et al. (2000) that cows on farms with deep bedded cubicles had about 10–20-fold less hairless patches, scabs and wounds than cows in cubicle barns with different mattresses. Also, Fulwider et al. (2007) found more cows with integer hocks in cubicles with deep sand bedding than with mattresses without any bedding material. Furthermore, in an experimental study (Mowbray et al., 2003), cows in deep bedded cubicles had lower rates of lesions at the tarsal joint than cows on mattresses with about 3 cm of bedding but without curb – resulting in decreasing bedding height over time, but on mattresses with bedding plus curb the difference in lesion rates to deep bedded cubicles was reduced almost completely, even after 3–6 weeks of cubicle use.

For lesions at the dorsal tuber calcis, the presence of a curb may also be a risk factor. Mowbray et al. (2003) observed higher average sizes of lesions at the tuber calcis in cubicles with exposed curbs. Also Fulwider et al. (2007) and Weary and Taszkun (2000) found higher prevalences of dorsal tuber calcis lesions in cows offered deep bedded cubicles compared with raised cubicles with mattresses or waterbeds. These findings were attributed to pressure or abrasive effects exerted by the curb on the dorsal tuber calcis if cows just fitted in the cubicle. Furthermore, Weary and
Taszkun (2000) found higher prevalences of lesions of the dorsal tuber calcis in deep saw dust bedding compared to deep sand bedding. They explained this result by the observation, that compression of the bedding material under the cows' weight was less in sand than in saw dust bedded cubicles, making the curb more protruding in the latter case. We took the possible effect of the curb on the tuber calcis into account by calculating an interaction factor between curb and shortness of the lying area. However this factor did not pass the selection procedure. One possible explanation for this is that lesions on the dorsal tuber calcis played a rather minor role with regard to the total lesion prevalence in our study: lesions of the dorsal surface of the tuber calcis were present in 19% of all examined cows.

In the context of the positive effect of bedding on hock integrity it seems surprising that the factors ‘curb’ and ‘absence of deep bedding’ turned out to have a significant effect, but not the height of bedding material, which was also offered for selection and has been found beneficial in a UK study (Potterton et al., 2011). This probably resulted from how the height of the bedding material had been measured. Only loose bedding material had been taken into account, because it was not feasible to measure the thickness of a straw dung mattress that often comprises a solid layer. However, such a solid layer may still significantly contribute to the elasticity of the lying place. We did further take this into account by applying a third measure which was the softness of the rear part of the lying area, subjectively assessed as hard, medium or soft. Hard lying areas accounted for an increase in HL prevalence of about 17% compared with soft lying surfaces in cubicles. This is in accordance with results from experimental comparisons between soft mattresses and rubber mats (Livesey et al., 2002). Additionally to total cubicle length, which has been identified as a relevant risk factor in other studies before (Weary and Taszkun, 2000; Busato et al., 2000; Fulwider et al., 2007), we offered an alternative measure of cubicle length for selection: the length available for the cow while lying. This was calculated by subtracting the head space from the total cubicle length (while taking cubicle type, regarding wall facing or face-to-face into account) or measuring the distance between brisket board and curb or end of lying area, respectively (Table 2). The effect of the length of the lying area had a stronger relation with HL prevalence than total cubicle length. Based on our results, increasing the length of the lying area by 20 cm would decrease HL prevalence by 6%. The benefit of a longer lying area to the cows hock area is obvious as lying on the edge of the cubicle or contact of the hock with the curb is prevented. This conforms to results of Potterton et al. (2011), who found decreased odds for hock swellings if the distance between curb and brisket board was larger than 178 cm, which is close to our mean and median value of 180 cm.

Finally, with regard to the cubicle design, the higher the free space under cubicle partitions was, the lower were HL prevalence levels. The same effect has been described by Mülleder and Waiblinger (2004): herds with cubicles giving less than 51 cm of space underneath the partition had on average 32% more cows with HLs compared to those with more than 51 cm. In cubicles with low partitions cows may have problems in shifting their positions in order to improve circulation. Also, the effect of collisions taking place while lying down may be amplified through a higher momentum of the collisions when bars of the partitions are lower. Additionally, collisions with the hock area seem only possible for very low partitions considering the height of the hock on the cows’ hind leg.

We found a rather weak positive relation between the proportion of cows with BCS scores ≥4.00 and HL prevalence. As the expected effect was deemed to be more physical than metabolic, we chose the same threshold for HF cows and Simmental. According to our regression model, 20% more overconditioned cows in the herd would account for 5% more cows with HL. This finding is contrary to findings on animal level showing a protective effect of higher BCS with regard to HL in general (Kieland et al., 2009) or hock swellings (Potterton et al., 2011), possibly due to less protruding bones in animals with higher body condition scores. In our study, the negative effect of a higher body weight seems to outweigh this possible benefit, presumably by resulting in higher pressure on the joints during the process of lying down and while lying. Additionally, this association found in our data set is on herd level, it thus might reflect general differences in the quality of herd management, affecting both, the percentage of cows being out of the recommended BCS range and the abundance of HL.

4.3. Relationship between hock lesions and lameness

We found a moderate relationship between HL and lameness on animal level as well as on herd level which is in line with findings of Rouha-Mülleder et al. (2010). This does not necessarily imply that HL are the cause of lameness. In several earlier studies it has been shown, that about 90% of all cases of lameness in cattle are due to claw problems and apparently only about 10% (range from 7.8 to 13.6%) are due to leg lesions (reviewed by ter Wee et al., 1989). Klaas et al. (2003) found that only the presence of severe swellings and suppurrative lesions significantly increased the individual risk of being lame. Still in this case it cannot be ruled out that an association between HL and lameness arose because lame cows might lie for longer times or have more difficulties standing up or lying down and, therefore, are at a greater risk to develop leg lesions. One other plausible explanation would be similar risks for lameness and leg lesions as found by Haskell et al. (2006) and Rutherford et al. (2008). This is supported by the fact that in the present data set characteristics related to lying showed the strongest influence on lameness (Dippel et al., 2009) as well as HL, with better lying comfort having a protective effect against both ailments. Clarification of the relation between lameness and leg lesions requires further investigation.

The relation between lameness and HL on animal level may suggest that the impact of risk factors may be larger on some animals than on others. This may be due to differences in cow size or weight (Haskell et al., 2006) making the same cubicles less suitable for bigger or heavier cows than for the “average cow” or be related to social status in the herd with low-ranking cows possibly having less choice
with regard to lying times and places (e.g. Wierenga, 1990; Galindo and Broom, 2000).

4.4. Recommendations for successful intervention

Based on our results and the cited findings, certain measures to improve cow welfare by decreasing HL prevalence appear to be promising. First, the choice of bedded cubicles can clearly be recommended. According to Wechsler et al. (2000) deep bedded cubicles do not only help to reduce the development of HL, but leg lesions in general. Similarly positive results regarding HL have been achieved with deep sand in Northern American studies (Weary and Taszkun, 2000; Vokey et al., 2001). Bedded cubicles do not necessarily imply that the lying area is soft. This largely depends on the kind of base of the cubicle and the proper maintenance of the bed. Therefore, providing a soft lying area is an important measure in itself, even more so because there will always be farmers not choosing deep bedded cubicles because of limited litter availability or for other reasons.

Intervention concerning the length of the lying area and the height of cubicle partitions should be considered, too. However, for the length of the lying area it may be assumed that more space increases the risk of soiling of the cubicles. A neck-rail in the proper position can help preventing this unwanted side effect (Tucker et al., 2005).

For determining an acceptable clear height of cubicle partitions, also risks for injuries at other parts of the body have to be considered. In short cubicles cows may take advantage of a greater freedom under cubicle partitions by positioning themselves diagonally in the cubicles and forcing their back underneath the partitions. This may result in serious injury of the spinal processes (personal observations).

We are aware that bedded cubicles or cubicles with more comfortable dimensions often result in increased labour demands for the farmer in order to keep hygienic conditions at a good level. However, their advantages for the prevention of injuries are supported by the results of this study. In light of the repeatedly confirmed high prevalence of HL, ways need to be found to achieve improvements for the good of the cows and farmers.

Another clearly recommendable preventative measure would be a good feeding management. Having cows in the recommended BCS range not only has possible beneficial effects on hock soundness but also on many other health aspects of the dairy cow.

5. Conclusions

HL pose a highly prevalent welfare issue for cubicle housed dairy cows and hence effective prevention strategies are needed. Lying comfort proved to have a strong influence on HL. Especially the provision of cubicles with deep bedding and a soft lying surface has high merits of preventing HL. Because of the association between HL and lameness, HL prevention has the potential to also improve lameness and thus lead to better dairy cow welfare.

Conflict of interest statement

The authors declare that they have no conflicts of interest regarding the present study and manuscript.

Acknowledgements

We thank the participating farmers for their interest and generous hospitality, Mrs. Feldmann for her instructions concerning body condition scoring, Annika Lucht and Jenni Humbert for their assistance with data collection and entry, and the milk boards and breeding associations of Niederösterreich, Oberösterreich, Steiermark, Baden-Württemberg, Bayern, Nordrhein-Westfalen, Schleswig-Holstein, ZAR and VIT Verden for helping with farm selection and milk report data.

This study has been co-financed by the European Commission, within the 6th Framework Programme, Contract No. FOOD-CT-2004-506508. The text represents the authors’ views and does not necessarily represent a position of the European Commission who will not be liable for the use made of such information.

References


