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Original Article

Area of hock hair loss in dairy cows: Risk factors and correlation to a categorical scale

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Abstract

Data from 3691 dairy cows from 76 farms were used to investigate the risk factors associated with area of hair loss over the lateral aspect of the hock, and the correlation between the area of hair loss as calculated using a hock map and hock lesion scores determined using a pre-existing categorical scale.

Six factors were associated with a greater area of hair loss, including cows with locomotion score 3, a cleanliness score (10-18/28), high daily milk yield (25.1 - 58.1 kg), poor body condition score (1-1.5), duration of winter housing (≥41 days) and some combinations of cubicle base and bedding materials. Compared with cows housed in cubicles with a concrete base and whole straw or rape straw bedding, cows housed in cubicles with concrete bases with sand or chopped straw bedding had smaller areas of hair loss and cows housed on a mattress base with whole straw or rape straw bedding had a larger area of hair loss.

Area of hair loss, as measured on hock maps, was not significantly different between cows with score 1 (median=23.6 cm^2) and score 2 (median=20.3 cm^2) on the categorical scale for hock lesions. This suggests that the categorical scale was not reflecting the extent of hair loss and that hock maps are a good alternative for studying the dynamics of hock lesions over time. Further work is required to explore the aetiology of hock lesions and find better ways to control this common condition.

Keywords: Hock lesions; Hair loss; Dairy cow; Welfare; Hock maps

Introduction

Hock lesions are commonly seen in housed dairy cows across the world including in the United Kingdom (Whay et al., 2003; Potterton et al., 2011b), Europe (Kielland et al., 2009; Brenninkmeyer et al., 2012), the USA (Fulwider et al., 2007; Lombard et al., 2010) and Canada (Weary and Taszkun, 2000). The term 'hock lesions' or 'hock injuries' has been widely used in the literature to describe a variety of presentations, including hair loss, broken skin, open wounds, scabs and localised swelling and swelling of the whole hock joint (Livesey et al., 2002; Huxley and Whay, 2006; Kielland et al., 2009). However, the three presentations that have been mostly commonly reported from around the world are hair loss, swelling and ulceration (Huxley and Whay, 2006). Of these, hair loss is the most prevalent presentation (Huxley et al., 2004; Potterton et al., 2011a) and is most commonly observed on the lateral aspects of the hock (Weary and Taszkun, 2000; Fulwider et al., 2007; Potterton et al., 2011b). The impact of hock lesions on the welfare of the animal is largely unknown (Huxley and Whay, 2006; Rutherford et al., 2008; Laven and Livesey, 2011). However, it has been assumed that the severity of hock lesions reflects the degree of comfort and the abrasiveness of the lying surface (Livesey et al., 2002; Lobeck et al., 2011; Brenninkmeyer et al., 2012), which may impact on welfare and health (Haskell et al., 2006; Huxley and Whay, 2006). Hock lesions are associated with an increased risk of lameness (Whay et al., 2003; Kielland et al., 2009; Brenninkmeyer et al., 2012) and injuries at other locations such as the udder and other joints (Sogstad et al., 2006).This suggests that they may be of use as welfare indicators (Whay et al., 2003; Regula et al., 2004).

The severity of hock lesions seen in dairy cattle varies from mild hair loss to open wounds and swelling (Weary and Taszkun, 2000; Kielland et al., 2009). However, there is a lack of understanding of how these lesions develop. The majority of studies on hock lesions have investigated risk factors associated with the presence or absence of hock lesions, amalgamating data from all lesion types (Regula et al., 2004; Rutherford et al., 2008; Kielland et al., 2009), based on the assumption that there is a linear progression from hair loss to swelling. However, Potterton et al. (2011a) investigated the risk factors for hair loss, ulceration and swelling separately and identified unique and shared risk factors for each presentation, suggesting that the assumption of a linear progression may be wrong.

It is unclear whether the factors identified by Potterton et al (2011a) as being associated with the presence of hock lesions also contribute to the extent and severity of lesions (in animals in which a lesion already exists) and/or whether there are additional risk factors in these animals. In order to establish this, more research is needed which focuses on lesion severity or extent

Categorical scales (Weary and Taszkun, 2000; Rutherford et al., 2008; Kielland et al., 2009) have been used to assess the severity of hock lesions including hair loss alone (Potterton et al., 2011a). However, there is currently no widely accepted, standard scoring system and there is little evidence on the reliability and validity of these scoring systems, nor how these scores equate to the area or areas of hair loss when measured objectively.

The aims of this study were to examine the area of hair loss on the lateral aspect of the hock using detailed hock maps of lesion area and to use these data to investigate: (1) the risk factors associated with area of hair loss measured; and (2) the correlation between hair loss measured by area and scores given on a categorical scale.

Materials and methods

Dataset and study methodology

A detailed description of the data collection and the study methodology used has been described and published previously (Potterton et al., 2011a, b). In brief, 76 farms in the Midlands region of the United Kingdom were visited during the winter housing period of 2007/2008. Approximately 50 cows were selected randomly from each herd for assessment. Selected cows were assessed for a wide range of animal characteristics including body condition score (scale 1-5) (Wildman et al., 1982), mobility score (scale 0-3; Whay et al., 2003), total cleanliness score (range 0-28) based on the sum of cleanliness scores recorded at seven separate sites including the tail, flanks and lower and upper hinds limbs on the left and right side (scale 0-4; Whay et al., 2003) and rising behaviour. Hair loss on both hocks for each animal were scored separately using 4-point categorical scales (score 0-3): hair undisturbed with no loss (score 0); area of hair loss <2 cm in diameter (score 1); area of hair loss 2-2.5 cm in diameter (score 2); area of hair loss >2.5 cm in diameter (score 3) (Whay et al., 2003). Additionally, the area and shape of hair loss at three locations over the hock (lateral, dorsal and the medial hocks) were recorded using hock maps. The location, areas and shape of partial hair loss (hair thinning without complete loss of hair cover) and complete hair loss (skin devoid of all hair) for both hocks for each cow were recorded separately as drawings (example provided in Fig.1; Potterton et al., 2011b). Following the animal assessment, a detailed evaluation of the farm and animal environment was conducted. All the cow and farm assessments were conducted by a single observer (SLP).

Following data collection, milk records and farm data were obtained to gather information on breed, age, parity, days in milk, duration of winter housing and milk yield (mean milk yield from the three most recent monthly milk records). Hock maps were scanned and stored electronically as JPEG images; areas in pixels of partial hair loss and complete hair loss were calculated using mathematical algorithms in a programme written in Matlab (The Mathworks). The area of hair loss in pixels was converted into cm^2 by using a scaling factor calculated from the mean width of 30 randomly measured hocks in cm divided by the distance in pixels from the hock map (Potterton et al., 2011b).

Data analysis

Hock map selection and analysis

A total of 3691 cows from 76 farms were selected for inclusion in this dataset. Out of 7382 hocks, 6896 (3447 left hocks and 3449 right hocks) had complete information on hair loss. The remaining 486 hocks were excluded because of missing data (n = 87) or dirty hocks that meant data could not be accurately recorded (n = 399).

Of the 6896 hocks, 6884 had complete hock maps; 12 could not be used due to technical difficulties. Of these 6884 maps, 1276 (18%) were excluded as they recorded no lesions (hair loss or any other lesion type) and thus leaving 5608 usable maps. A total of 5431/5608 (97%) hocks had some area of partial hair loss and of those almost all had area of partial hair loss (5352/5431; 99%) on the lateral surface. Thus a statistical model was constructed to explore factors associated with larger area of hair loss on the lateral hock surface.

Of the 5352 hocks with an area of partial hair loss on the lateral side, 2296 hocks (43 %) also had an area of complete hair loss. Of these 2296 hocks that had an area of both partial and complete hair loss, 2143 (93 %) hocks had an area of complete hair loss surrounded by an area of partial hair loss, whereas only 95 hocks (4.%) had an area of complete hair loss not surrounded by an area of partial hair loss. Only 58 (3%) hocks had some area of complete hair loss surrounded by an area of partial hair loss plus another area of complete hair loss not surrounded by an area of partial hair loss. Examples of these areas of hair loss are presented in Fig.2. These 95 hocks plus 58 hocks were excluded. Finally, 13 hocks were excluded from the dataset because the animal identity could not be confirmed. The final dataset used in the univariable and multivariable analysis contained a total of 5186 hocks (from 2996 cows).

Factors associated with area of hair loss on the lateral surface of the hock

A multilevel linear model was built with three levels: farm, cow and hock (Rasbash et al., 2012). The outcome variable was log-transformed area of hair loss on the lateral surface. A total of 94 potential variables collected on farm were tested in the analysis; these are presented in Table 1. Univariable analysis was performed and those variables where $P \leq 0.10$, were retained and taken forward for further analysis. Variables with large numbers of missing values were excluded. A stepwise regression selection method was used to obtain an appropriate final model. The model was created in MLwiN version 2.25 (Centre for Multilevel Modelling, University of Bristol) and fitted using iterative generalized least squares estimation. Variables with a $P \leq 0.05$ were retained in the multivariable model.

The outcome variable was log transformed and therefore model specifications were

$$\text{Log } (Y_{ijk})=\beta_0+ \beta_1 X_{ijk} + f_k+ u_{jk}+ e_{ijk}$$

$$f_k \sim N(0, \sigma^2_f),\ u_{jk} \sim N(0, \sigma^2_u),\ e_{ijk} \sim N(0,\sigma^2_e)$$

where Y_{ijk} is an area of hair loss on the lateral surface of the hock_{ijk}, β_0 is the intercept, the subscript i, j, k represent the hock, cow and farm levels respectively. β_1 was coefficients of explanatory variables expressed as X_{ijk}, and f_k, u_{jk}, e_{ijk} as random effects of residual variation between farm, cow and hock level respectively which were assumed to follow a normal distribution with mean zero and variance σ^2. The Chi square test/Fisher's exact test was used to test association between these categorical explanatory variables. If variables were strongly associated, only one of the variables was selected. The model fit was checked by residual plots at each level.

Correlations between hair loss measured by area on the hock maps and scores given on a categorical scale

The area of hair loss on the lateral surface of each hock measured on the hock maps was compared with categorical hock lesion scores by using Mann-Whitney tests to assess differences in the area of lesions between scores on the categorical scale.

Results

Risk factors associated with area of hair loss on the lateral surface of the hock

Mean area of hair loss across all cows was 22.3 cm^2. Of all the risk factors explored, six were significant in the final multivariable model (Table 2). Cows with locomotion score 3, i.e. severely impaired mobility, with a total cleanliness score between 10-18 i.e. moderately dirty, higher mean milk yield (cows producing between 25.1 - 40.0 kg/day and 40.1 - 58.1 kg/day), cows housed between 41-76 days and more than 76 days had a significantly greater area of hair loss . Cows with a BCS of 2 had smaller area of hair loss compared to cows with a BCS between 1 and 1.5.

Cows housed in cubicles with a concrete base and sand bedding or a concrete base with chopped straw bedding had a significantly smaller area of hair loss; cows housed in cubicles with a mattress base and whole straw or rape straw had a significantly larger area of hair loss compared with cows housed in cubicles with a concrete base and whole straw or rape straw bedding.

There were significant associations between some variables in the final multivariable model and other explanatory variables; mean milk yield was significantly positively associated with parity. There were significant associations between the type of base bedding used in the cubicle and the mean depth of the bedding material (Table 3). The residuals plots (Fig.3) suggested model fitted the data well.

Correlation between hair loss measured by area on the hock maps and scores given on a categorical scale

There were 2072 hocks with an area of hair loss on the lateral surface only (i.e. excluding those that had hair loss on the medial or dorsal surface). The minimum and maximum values for the area of hair loss were $0.4cm^2$ and $141.4cm^2$. The distribution of area of hair loss within their allocated categorical scores is presented in Table 4, Fig. 4 respectively. The median area of hair loss was not different between scores 1 and score 2 (z=1.58, P=0.11); score 3 had a significantly higher area of hair loss compared with score 2 (z =-11.53, P<0.001).

Discussion

To the authors' knowledge this is the first paper to explore the risk factors associated with the extent of hair loss on the hock, based on the area measured on a continuous scale. This study has identified significant differences between risk factors associated the presence of hair loss and the extent of that loss.

Firstly, factors such as the application of hygiene products to bedding, the time mats and mattress have been in cubicles and some features of cubicle design (bed length, height of lowest side rail at the head end, distance from the neck rail to the cubicle step) were all reported by Potterton et al. (2011a) as being associated with the presence of hair loss, but were not associated with extent of hair loss in the current study. It suggests that these factors contribute only to the occurrence of hair loss in the first place; once a lesion is present these factors don't contribute to the extent of hair loss.

Secondly, this study has identified risk factors, low body condition score and poor cleanliness score, which were not found by Potterton et al. (2011a) to be significant in relation to the presence or absence of hair loss but which were associated with increased extent of such lesions. It is also possible that these factors act more as reinforcing factors and contribute to the exacerbation of hair loss once a lesion is established.

The positive association between locomotion score and hock lesions including hair loss (Potterton et al., 2011a) is now well established (Whay et al., 2003; Regula et al., 2004; Kielland et al., 2009; Brenninkmeyer et al., 2012); this was also demonstrated for extent of hair loss in the current study. However, these associations of lameness and body condition with extent of hair loss on hocks are further complicated by the growing weight of evidence which suggests that low body condition score is a risk factor for lameness caused by claw horn lesions (Green et al., 2014). Whilst results from cross sectional studies such as this give no indication of causality, there are a number of possible and biologically plausible explanations. For example, cows with low body condition score are more likely to become lame, there is now increasing evidence of this association due to possible thinning of the digital cushion predisposing animals to lameness (Bicalho et al., 2009; Lim et al., submitted), which may then alter their lying behaviour (e.g. lying time and lying bouts) making them more likely to develop a larger area of hock hair loss. Alternatively, lame cows may have more difficulty standing up or lying down leading to bony protrusions such as the hock crashing into cubicle architecture resulting in a larger area of hock hair loss. This effect will be exacerbated if lame cows are not treated promptly and effectively, prolonging the duration over which animals are lame. Equally it could be that being thin is a shared risk factor for both lameness and hock hair loss lesions via different mechanisms. Future randomised controlled trials are required to tease apart these interesting and important relationships.

In the current study high milk yield and days of housing were associated with increased area of hair loss and were also reported by Potterton et al. (2011a) as being associated with the presence of hair loss. It is difficult to see how these risk factors could be practically managed on the majority of farms, to reduce the risk of lesion progression. Target milk yield is a fundamental farm management decision which underpins the financial operation of the business and the necessity for and duration of the housing period is predominantly forced by climatic conditions. Where producers do have an option, our results suggest that decreasing the duration of the housing period may help to decrease the extent of hock hair loss lesions.

Lying surface significantly impacts on the severity of all types of hock lesions; sand or chopped straw on a concrete base were associated with less severe hair loss and straw on a mattress base was associated with more severe hair loss. Of the six risk factors identified, the lying surface in the cubicle has the most practical potential to be altered to reduce the extent/severity of hair loss lesions (particularly increasing the depth of the bedding material provided). Unfortunately this area is complex as there were three principal variables to the lying surface: the cubicle base, the material placed on the base and the depth of bedding material provided. This created a number of difficulties in this study; firstly there were many different possible combinations of base and material, which reduced the power of the analysis. Secondly, aspects of base, material and depth of bedding were correlated in this dataset (e.g. sand was predominantly provided as a deep bed) making it difficult to tease out exactly which combinations were protective. Though, these results do indicate that both chopped straw on a concrete base and sand on a concrete base were associated with less severe lesions. There are a number of possible explanations for these findings. Sand has been shown to offer more protection due to its lack of compression and inert nature (Kudi et al., 2009; DairyCo., 2014), it also provides more purchase during lying and standing, which may reduce joint abrasion and concussion during these complex movements in confined spaces. Chopped straw has been shown to have better absorbency than whole straw (Tuyttens, 2005), this may limit skin maceration caused by lying on wet bedding which may be protective against lesion progression. However it is worth noting that all the observations for chopped straw on a concrete base were from one study farm, and it is possible that the protective effect on this farm was down to an unidentified factor that was correlated with the cubicle lying surface. Intervention studies are required to conclusively demonstrate which combinations of base, bedding material and bedding depth prove the most protection against hair loss severity.

In this study, the area of both partial and complete hair loss (within partial hair loss) was selected as the outcome variable. The lesion area could therefore be composed of any combination of partial and/or complete hair loss in any proportions. This approach was selected because it took into account the total area of hock being abraded on the day the animal was assessed. Firstly this gives a more complete description of the affected area and secondly it avoids the assumption that more visually impressive lesions (i.e. with complete hair loss) are more severe, an assumption for which evidence is currently lacking.

A comparison between hair loss measured from the hock maps and the scores given for hair loss on the categorical scales, indicated that there was substantial cross over between them (Fig. 2). For categorical scores 1 and 2 the median and range of values for the areas of hair loss were very similar. This suggests that these categories are not differentiating the degrees of severity/extent of hair loss. As discussed above, the area data for lesions included areas of both partial and complete hair loss. In the categorical scoring scale there is no differentiation between these two presentations and it’s possible that this lack of clear definitions in the categorical scores contributed to this finding. In contrast, whilst the hock maps were more time consuming to collect they provided substantially more detail on the size, location and extent of the hair loss lesion(s) present and the nature of the assessment made them relatively more objective than the categorical scores. As it is currently unclear which aspects of these hair loss lesions have the greatest impact on welfare and production, hock maps could provide us useful insight to better understand the consequences of hock lesions by looking into the relative importance of size, degree of hair loss or other aspects of lesion pathology. Further studies are required to test the intra- and inter- reliability of data captured on hock maps, to further validate their use for research purposes (e.g. continuous monitoring of hock lesions over time).

Conclusions

This study suggests that there may be factors (e.g. poor BCS and cleanliness) that act as reinforcing factors leading to larger area of hair loss once a lesion is established. Categorical scales available for hair loss might not be valid tools to differentiate the severity/extent of these lesions and hock maps offer a good alternative. Finally, hock maps could be used in longitudinal studies to monitor the development and progression of hair loss over the time, furthering our understanding of disease aetiology and its impact on both the welfare and productivity of intensively managed dairy cows. Ultimately this will help develop on-farm control strategy and increase the awareness of farmers to the importance of this prevalent disease.

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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Table 1

List of potential risk factors for area of hair loss on the lateral surface of the hock

Cow level risk factors	
Categories(number of variables)	Descriptions
Cow characteristics(12)	BCS, locomotion score, cleanliness score (7 separate areas), parity, age, breed
Milk yield (9)	Days in milk, most recently recorded milk yield, previous lactational 305 day yield, mean milk yield from the 3 most recent monthly milk records
Cow behaviours (8)	Rising and lying behaviours
Farm level risk factors	
Environment assessments (27)	Measurement and condition records of feed space, passageways, loafing areas, floor type, bedding materials, cubicle type, depth of bedding material
Stall measurements (13)	Total length, distance from the curb to the brisket positioner, length of any mat or mattress, width, curb height, width of curb left exposed when a mat or mattress was present, height of brisket positioner, distance from the neck rail to the curb (on the diagonal), height of neck rail, height of the lowest side rail at both the rear (40 cm in from rear of bed) and front of the cubicle(at point of brisket positioner), and distance between lower and upper side rails at the front end of the cubicle(at point of brisket positioner)
Cubicle features (13)	Proportion of cubicles with broken sides, neck rails, incorrectly positioned mats and mattresses, nonparallel side rails, side lunge space available on just one side, interrupted forward lunge or bob space and directly facing a wall
Management practices (12)	Hygiene products related variables, herd size, stocking rate, days of winter housing, frequency of bedding material replenishment

* Full description of cow selections and measurements of risk factors have been described at Potterton et al. (2011a).

Table 2

Risk factors associated with area of hair loss on the lateral hock surface in the multilevel linear model

Variable	Freq. hocks	Freq. cows	Coefficient	CI 2.50%	CI 97.50%	*P* -value	
Intercept	5186	2996	22.3 cm^2				
Locomotion score							
Score 0	2240	1306	Reference				
Score 1	892	509	1.03	0.94	1.14	0.49	
Score 2	1521	878	1.01	0.93	1.10	0.78	
Score 3	354	200	1.22	1.06	1.39	0.004	*
[a]Total cleanliness score							
2-9	437	256	Reference				
10-18	4492	2581	1.17	1.03	1.33	0.02	*
19-27	133	86	1.18	0.91	1.52	0.21	
Mean milk yield (kg)							
2.4-25.0	1800	1056	Reference				
25.1-40.0	2093	1195	1.11	1.03	1.19	0.01	*
40.1-58.1	435	254	1.25	1.09	1.43	0.002	*
Body condition score							
1-1.5	1339	782	Reference				
2	2143	1246	0.90	0.82	0.98	0.01	*
2.5-4.5	1655	942	0.93	0.84	1.02	0.14	
Days of winter housing							
2-40	1045	614	Reference				
41-76	1073	617	1.24	1.04	1.48	0.02	*
>76	2082	1207	1.19	1.00	1.41	0.04	*

Continued

* $P \leq 0.05$, Freq.: frequency, CI: confidence interval
[a]The total cleanliness score was a summation of 7 separate areas including the tail, left and right flanks, left and right lower hind limbs and left and right upper hind limb.

Table 2(Continued)

Risk factors associated with area of hair loss on the lateral hock surface in the multilevel linear model

Variable	Freq. hocks	Freq. cows	Coefficient	CI 2.50%	CI 97.50%	*P* -value	
Base and bedding material in the cubicle							
Concrete with whole straw or rape straw	235	149	Reference				
Concrete with sawdust or wood shaving	133	81	1.16	0.72	1.88	0.54	
Concrete with sand	169	107	0.46	0.30	0.70	<0.001	*
Concrete with chopped straw	46	32	0.27	0.15	0.52	<0.001	*
Mattress with sawdust or wood shaving	760	413	1.02	0.73	1.42	0.92	
Mattress with whole straw or rape straw	208	112	1.47	1.04	2.09	0.03	*
Mattress with chopped straw	185	99	0.78	0.42	1.44	0.43	
Mattress with other bedding	86	46	0.76	0.41	1.41	0.38	
Mat with sawdust or wood shaving	485	267	0.78	0.56	1.09	0.14	
Mat with sand	34	22	0.72	0.37	1.40	0.34	
Mat with whole straw or rape straw	58	31	1.42	0.76	2.66	0.28	
Mat with chopped straw	223	124	1.02	0.67	1.55	0.93	
Mat with other bedding	78	45	0.78	0.42	1.47	0.45	
Other base with sawdust or wood shaving	163	91	1.22	0.76	1.97	0.41	
Other base with whole straw or rape straw	688	397	0.97	0.70	1.33	0.84	
Other base with other bedding	88	48	0.76	0.40	1.43	0.39	

* $P \leq 0.05$, Freq.: frequency, CI: confidence interval

Table 3

Mean depth of bedding material in cubicles with different base and bedding materials

Base and bedding	Mean depth of bedding material (cm)			
	0-2 cm	3-4 cm	5-6 cm	7-12 cm
Mattress with whole straw or rape straw	164 (78.85%)	44 (21.15%)	-	-
Concrete with whole straw or rape straw	63 (26.81%)	84 (35.74%)	88 (37.45%)	-
Concrete with sand	-	70 (41.42%)	-	99 (58.58%)
Concrete with chopped straw	-	-	-	46 (100%)

Table 4

Distribution of area of hair loss within their allocated categorical scores

Categorical scale	Area of hair loss (cm^2)	
Score	Frequency (%)	Median (IQR)
1	1215 (58.64%)	23.6 (8.3-47.5)
2	562 (27.12%)	20.3 (9.0-40.5)
3	295 (14.24%)	42.4 (28.2-63.5)
Total	2072	

Figure legends

Fig.1. Example of a hock map used for data collection in this study

Fig.2. Examples of different locations of partial hair loss and complete hair loss on the lateral surface of the hock as measured by hock maps.

a) Area of complete hair loss which is surrounded by an area of partial hair loss. b) Area of complete hair loss which is not surrounded by an area of partial hair loss. c) Area of complete hair loss which is surrounded by an area of partial hair loss plus another area of complete hair loss which is not surrounded by area of partial hair loss.

(Key: straight line- area of partial hair loss; dash line- area of complete hair loss)

Fig.3. Residual plots for farm (a), cow (b) and hock (c) levels of multilevel linear model of area of hair loss on the lateral surface of the hock respectively

Fig.4. The distribution of area of hair loss on the lateral hock scored on a categorial scale