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THE INFLUENCE OF HOUSING ON CLAW LAMENESS IN DAIRY CATTLE

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Abstract

Lameness in dairy cattle remains an important issue because of economic losses and the negative effects on animal welfare. In the present study, the aim was to investigate the effects of housing parameters on claw lameness in dairy cattle. The Cow Comfort Scoring system of van Eerdenburg was used assessing housing parameters and cow comfort on 14 Dutch commercial dairy farms. The 14 farms were visited once between March and July 2011. A total of 1626 lactating dairy cows were individually scored with the locomotion score by Sprecher. The exorotation of the hindleg and claw measurements from the hindleg claw were also taken from those dairy cows. It was expected that incorrect housing, especially cubicles and flooring, and insufficient cow comfort would lead to lameness. Additionally, the hypothesis was that claw measurements and exorotation of the hindleg had a good predictive value for lameness.

The average lameness prevalence in this study was 39% (range=22-56%), while 14% (range=3-32%) of dairy cows had locomotion score 3 or higher according to the locomotion scoring system of Sprecher. The Cow Comfort Score (average 262 out of 500 range=169-334) had a significant predictive value for lameness when considering locomotion score 3 and higher ($R^2 = 0,282/P = 0,051$). Furthermore, this study supports the hypothesis that exorotation of the hindleg and the length of the claw affect lameness. This study did not find a significant relation between lameness and cubicle conditions or cubicle dimensions. However, 'Cows standing in idle,' which is a sign of decreased lying comfort, did show a significant relation with lameness. Flooring was not significant, but the 'Width of the alleys' was. Possible explanation is that this study contained only a small amount of observed farms and only 3/14 farms had sufficiently good housing and cow comfort, which also leads to less variation and as a result it has proven to be difficult to statistically prove predictive parameters for lameness.

Introduction

Importance of lameness on dairy farms

Lameness remains a major concern on dairy cattle farms. The prevalence varies greatly among dairy farms across the world. Various studies show percentages of lame dairy cattle ranging from 0% to 79% (Rouha-Mülleder et al. 2009, Barker et al. 2010). This indicates that it is possible to have low lameness prevalence on a dairy farm. However, many farms do not achieve this. Precise numbers on the prevalence of lameness in Dutch dairy cattle are frequently absent or outdated. Studies in the past reported that 21% and 26% of the Dutch dairy cattle suffered from lameness (Barkema et al. 1994, Enting et al. 1997). An evident higher prevalence of 36,8% was found in a more recent extensive study in England and Wales (Barker et al. 2010). Therefore, it seems more important to understand and investigate what the causes and consequences of lameness are in dairy cattle.

One of the main reasons that lameness in dairy cattle continues to be a prominent issue is because of the economic consequences and the consequences for animal welfare. Warnick et al. (2001) reported that there was significant decrease in milk yield for diagnosed lame cows (Warnick et al. 2001). Apart from the decrease in milk yield, the following costs should be considered: veterinary fees, costs of medication, value of time nursing the cow, decreased reproductive efficiency, earlier culling and loss of body condition (Greenough 2007). Furthermore, the increasing milk price and heifer costs can easily affect the monetary value of an individual lame dairy cow. A recent study concluded that the costs of sole ulcer, digital dermatitis and foot rot were US\$ 216.07, 132.96 and 120.70, respectively (Cha et al. 2010). Another important issue is how lameness influences the welfare of the dairy cows. The Brambell Committee composed the Five Freedoms to determine welfare in intensive animal husbandry. The freedom to be free of pain, injury and disease is said to be the most important (Webster 1986, Farm Animal Welfare Council 2009). Whay et al. (1997) stated that lameness is related to hyperalgesia. Lame heifers significantly reacted on applied mechanical noxious stimuli on the lame leg (Whay, Waterman & Webster 1997). The Faculty of Veterinary Medicine in Utrecht describes animal welfare as the adaptive capacity of an individual animal whereby the animal stays in a state of mind that is experienced as pleasant (Ohl et al. 2009). Lameness, therefore, can be considered as a failing adaptive capacity to the

(artificial) environment. There is enough evidence that lameness is a sign of discomfort, (very) painful, and thus a considerable welfare issue.

Housing parameters

Most dairy cattle, especially in the Northern hemisphere, are kept in free stall housing. The housing system contains two main issues on which a substantial amount of research is done: cubicles and flooring. Cubicles need to be comfortable for the dairy cow and hygienic (Greenough 2007, van Eerdenburg, Saltijeral-Oaxaca & Vázquez-Flores 2009). Decreasing lying comfort is, for example, explained by neck rail distances that are too short, mattresses or rubber mats instead of deep-bedded stall bases and insufficient lunge space (Dippel et al. 2009). Previous studies report that shorter cubicles induced more hock lesions and lameness (Haskell et al. 2006, Weary, Taszkun 2000). The type of bedding also influences the prevalence of hock lesions, with geotextile mattresses 91% over 24% in barns with sand-bedded stalls (Weary, Taszkun 2000). Dimensions for cubicles are a deliberation between cow comfort and workload for farmers. If, for example, the neck rail is too high the cubicles become dirty, while too low prevents the cow from rising naturally (van Eerdenburg, Saltijeral-Oaxaca & Vázquez-Flores 2009). Normally a cow will lie down for 12-14 hours per day (Dippel et al. 2009). Lamé cows have longer lying bouts and shorter feeding time (Somers 2004). But when the lying comfort decreases, the lying bouts also decrease and prevalence of lameness increases (Dippel et al. 2009). With good sand bedding, however, there is an increase in lying time for lame cows (Cook, Bennett & Nordlund 2004).

If, as mentioned above, a cow lays down 12-14 hours, it needs to stand or walk the other 10-12 hours. In those 10-12 hours the eating, drinking, being milked and waiting for the milking parlor are also included. Excessive standing leads to decreased blood flow in the claw and excessive walking may lead to over-wearing of the soles. Floors that are too slippery may cause injury to dairy cattle due to inadequate footing, while too rough flooring leads to too much sole erosion (Curt, Cooch 2000). It is possible to put rubber topping on concrete. The rubber-topped floors show significant fewer sole hemorrhages (Ouweltjes et al. 2009) It is also reported that dairy cows show more walking activity on rubber-topped floors. Rubber-topped floors give better claw health than concrete floors (Ouweltjes et al. 2009, Kremer et al. 2007).

The Cow Comfort Scoring system from Van Eerdenburg et al. (2013) is designed to make an assessment of the cow comfort in free stall housing. It uses housing parameters to measure animal welfare. The Cow Comfort Score is divided in different chapters, including: general, light, ventilation, cubicles, flooring, feeding fence, water, walkways and alleys, miscellaneous, and animal health (van Eerdenburg et al. 2013). So besides the well-known housing parameters flooring en cubicles, the Cow Comfort Score includes more housing parameters given a more comprehensive representation of housing parameters and making it possible to assess animal welfare of dairy cattle more thoroughly.

Aim of this study

Since 90% of the lameness is caused by a problem of the claw, it is important to signal when claw diseases may occur (Greenough 2007)The aim of this study is to investigate the effects of housing parameters on claw lameness in dairy cattle. The main hypothesis of this study is that there is a correlation between the general level of cow comfort on a dairy farm and lameness. The Cow Comfort Scoring system from Van Eerdenbrug et al. (2013) is expected to be a good predictor for lameness. It is expected that incorrect housing, in particular measurements of the cubicles and flooring, lead to negative effect on the prevalence of lameness. Furthermore, it is expected that measurements of the claw can indicate lameness. Claws that have more contact area with the floor will lead to more lameness.

Materials and methods

Farms

This study was conducted on 14 commercial dairy farms in the Netherlands. Farms were selected by several selection criteria: herd size > 45 dairy cows, non-organic and no major adjustments in the housing system during the last 3 months. In addition, farmers had to be willing to collaborate on the study. 4 dairy herds that were included in this study had deep litter bedding. The other 10 farms had cow mattresses or mats. On most farms all lactating dairy cows were included in the study. For practical reasons, namely the large herd size, it was decided to take a selection of the lactating cows on farms 3, 7 and 11. The cows were randomly selected, whereby the selection was at least half of the total herd size at the farms. On farm 8 and 12 the cows of only one side of the feeding alley were included in the study, otherwise cows were fixed too long at the feeding fence. The farms were visited between March and July 2011. All farms were visited once.

Collecting results

All cows were individually scored according to the lameness scoring system designed by Sprecher (table 1). This scoring system has a scale from 1 -5 in which 1 is a sound gait and 5 is used for very lame cows. On eight farms, the observer stood in the pit of the milking parlor. At the remaining farms, cows were observed from a distance on a flat surface. When cows scored a 2 they were considered to be mildly lame. Most farmers consider score 3 as lame, while Sprecher gives lameness score 2 the clinical description 'mildly lame' (Sprecher, Hostetler & Kaneene 1997). For that reason there are two lameness fractions used in this study. Prevalence 'Lameness1' is score 3 or higher, prevalence 'Lameness2' is score 2 or higher. Cows were individually identified by collar or freezebrand.

Lameness score	Clinical description	Assessment criteria
1	Normal	The cow stands and walks with a level-back posture. Her gait is normal
2	Mildly lame	The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal
3	Moderately lame	An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs
4	Lame	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favours one or more limbs/feet
5	Severely lame	The cow additionally demonstrated an inability or extreme reluctance to bear weight on one or more limbs/feet

Table 1: Locomotion scoring system according to Sprecher et al. (1997)

The claw of the hindleg was measured as the cows stood in the milking parlor or as the cows were fixed at the feeding fence. At all farms the same observer assessed the cows and used the same folder ruler to measure the claw. The measurements of the hindleg were taken because there is possible correlation between anatomic measurements of the claw and lameness. The dorsal border of the claw was measured in the same way as in previous studies Gomez et al 2003 and Somers et al 2004 (Somers et al. 2005, Gómez, de Boer & van Eerdenburg 2003). The part of the claw that has contact with the floor while standing was also measured (in this study referred to as 'Length of the claw'). In addition, the foot angle was scored using a three point system in which 1 was given when the exorotation of the hind feet relative to the spinal column was $< 17^{\circ}$. Score 2 was given when exorotation of the hindfeet was between 17° - 24° and score 3 was assigned to cows with an exorotation of the hindfeet above 24° (Gómez, de Boer & van Eerdenburg 2003)

Each farm was assessed on several housing system requirements according to the Cow Comfort Scoring system designed by Van Eerdenburg et al, (2013) (appendix 1). Also the walking alleys, cubicles and feeding fence height were measured.

Statistical analysis

Statistical analysis was performed with $n = 14$. All individual cow measurements and scores were combined to an average for each farm. The Cow Comfort Score is a parameter that is similar for all lactating dairy cows on the same farm. Statistical analyses were performed with IBM-SPSS 22 and excel 2011. In order to correlate lameness to anatomic measurements of the claw three anatomic measurements were taken into consideration. The average score of each farm was made for the following

measurements: dorsal border of the claw, part that makes contact with the floor while standing (in this study referred to as 'Length of the claw') and the sum of the previous two (in this study referred to as 'Claw measurements'). The prevalence of exorotation of the hindleg is calculated as the percentage of dairy cows with a score 2 and 3 on each farm. Lameness was described in the following two parameters: prevalence lameness score 3 or higher (in this study referred to as 'Lameness1') and prevalence lameness score 2 or higher (in this study referred to as 'Lameness2'). The lameness fraction was normally distributed after transformed by logarithm (Q-Q plot in appendix 2). When relating lameness to the Cow Comfort Score the chapter 'Animal health' was not used entirely. The following individual items were excluded because the observer could not receive objective data on all farms: mastitis, abomasal displacement, problems with calving, milking fever, fertility and acetonemia. Lameness was excluded because lameness was the parameter that Cow Comfort Score was related to. Regression analysis is used to describe cause-and-effect relationship between two (or more) variables. R square is a measurement for how strong or weak the causality is. The relation was considered significant when the P-value was $\leq 0,05$ and a trend when P-value was $\leq 0,07$.

Results

A total of 1626 lactating dairy cows were individually scored on 14 Dutch commercial dairy farms. The average lameness prevalence ('Lameness2') in this study was 38,56% and ranged from 22% up to 56% (median 37,88%; SD 10,97). Clearly recognizable lameness ('Lameness1') was reported on every Dutch commercial dairy farm in this study ranging from 3,21% to 32,31% with an average of 13,73% (median 11,26%; SD 9,08).

In this study the average Cow Comfort Score was 262 points out of the total 500 points, whereby the lowest score was 174 points and the highest score was 339 (median 260; SD 48). For the adjusted Cow Comfort Score (with the adjusted chapter 'Animal health') the average was 213 points out of the total 400 points (median 194; SD 39).

Lameness and anatomic measurements

There was a significant relation between lameness and the exorotation of the hindleg and anatomic measurements of the claw. Lactating dairy cows with longer claws (larger contact area with the floor) showed more lameness. There was no significant relation between lameness and the dorsal border of the claw (table 2). The exorotation of the hindleg is significant related to Lameness1 and Lameness2, R^2 0,391/P 0,017, R^2 0,347/P 0,027, respectively. When length of the claw and the exorotation of the hindleg are combined in a multivariable regression it leads to a significant relation, R^2 0,510/ P 0,020 (appendix 3).

Relation between lameness and anatomic measurements claw
(R square/P-value)

Lameness1 and claw measurements	0,339/0,029*
Lameness2 and claw measurements	0,257/0,064
Lameness1 and length of the claw	0,376/0,020*
Lameness2 and length of the claw	0,193/0,116
Lameness1 and length dorsal border	0,032/0,544
Lameness2 and length dorsal border	0,056/0,414

Table 2: Relation between lameness and anatomic measurements claw (=significant).*

Lameness and Cow Comfort Score

There is a significant relation between Lameness1 and the adjusted Cow Comfort Score (R^2 0,282 /P 0,051). No significant relation was found between Lameness2 and the Cow Comfort Score (R^2 0,160 /P 0,157).

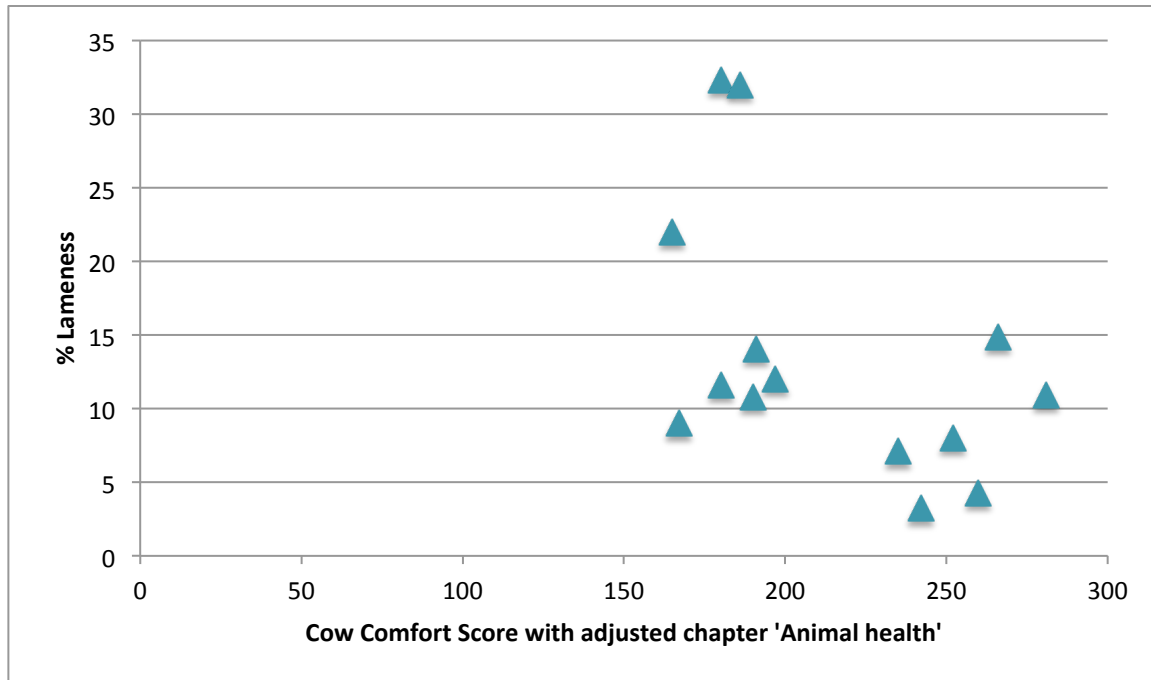


Figure 1: Prevalence Lameness1 (locomotion score ≥ 3) vs. adjusted Cow Comfort Score.

The main chapters of the Cow Comfort Score were individually correlated with lameness (table 3). Also the individual items of the Cow Comfort Score were analysed using linear regression test (appendix 4). 'Light', 'Ventilation', 'Water', 'Concentrate dispenser' and 'Miscellaneous' did not show a significant relation, neither the individual items of these items.

Parameter	log Lameness1		log Lameness2	
	R square	P-value	R square	P-value
General	0,524	*0,003	0,220	0,090
Light	0,005	0,817	0,053	0,427
Ventilation	0,129	0,208	0,001	0,904
cubicles/free stalls	0,016	0,668	0,005	0,814
Flooring	0,270	^0,057	0,023	0,605
feeding fence	0,217	0,093	0,248	*0,048
concentrate dispenser	0,007	0,774	0,004	0,834
Water	0,004	0,840	0,017	0,655

waiting room and milking parlor	0,067	0,373	0,004	0,830
walkways and alleys	0,202	0,107	0,016	0,670
Miscellaneous	0,037	0,509	0,028	0,566
(Adjusted) animal health	0,055	0,421	0,290	*0,047

Table 3: Main items Cow Comfort Score (*=significant; ^=trend)

Cubicles

In the Cow Comfort Score a minimum amount of points for the main chapter 'Cubicles' is 40 points out of the maximal 70 points (red line in figure 2). In this study 4/14 farms met the minimal requirements.

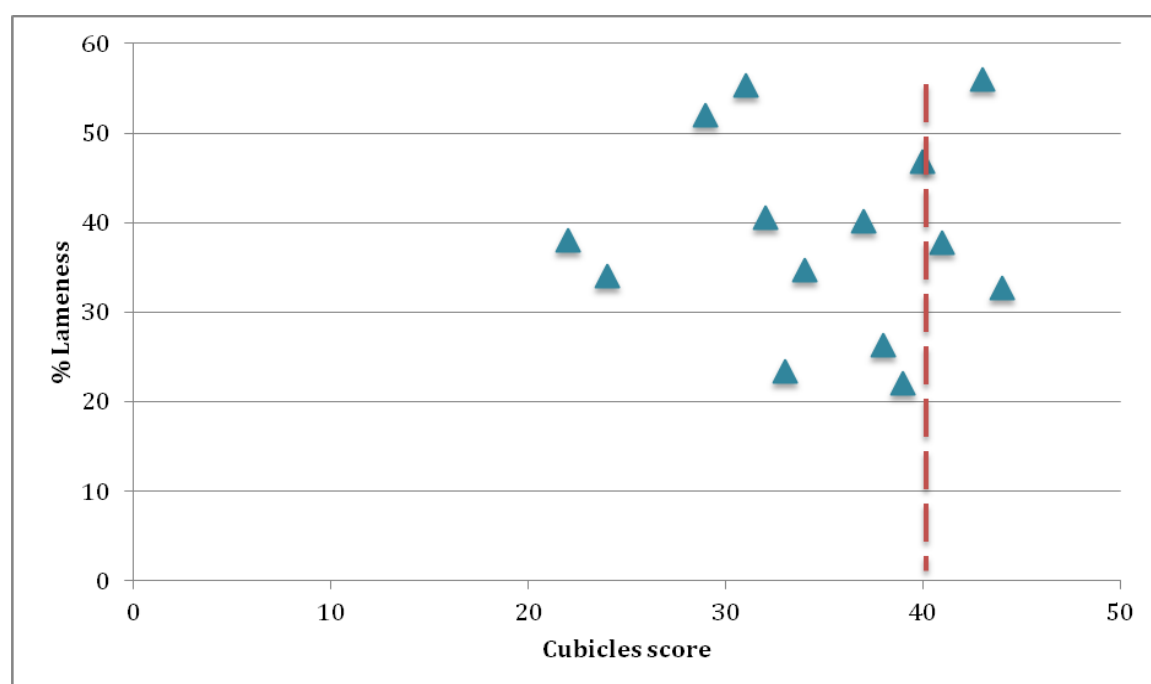


Figure 2: Lameness2 percentages (locomotion score ≥ 2) vs. Cubicles score of the Cow Comfort Score

There was no significant relation found between lameness and main chapter 'Cubicles.' However, Lameness2 and 'Bedding is flat' did show a significant relation (R^2 0,478 / P 0,006). The item 'Standing idle,' which is a part of main chapter 'General,' is often used as an indicator for decreased lying comfort. Therefore, 'Standing idle' is used together with 'Number of cubicles,' 'Length/width of the stall,' 'Lunge space,' 'Bedding is flat' in a multiregression which resulted in a significant relation (R^2 0,880 / P 0,002) (appendix 5).

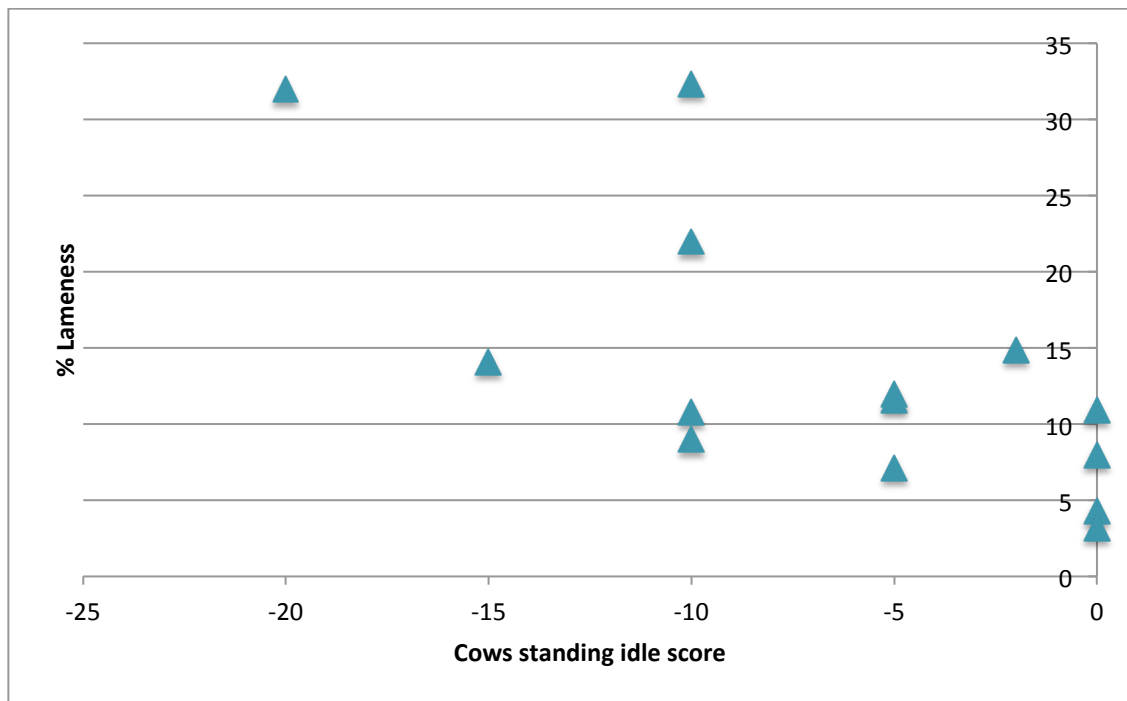


Figure 3: Lameness1 percentages vs Cows standing idle (R^2 0,490, P 0,005)

Flooring

There was a trend ($p = 0,057$) for the relation between Lameness1 and chapter 'Flooring.' There was no significant relation found between individual items of 'Flooring' and lameness. Yet, when combining 'Slipperiness', 'width of the alley behind the feeding fence' and 'width of other alleys' in a multiregression analysis, a trend was observed (R^2 0,514 / P 0,057).

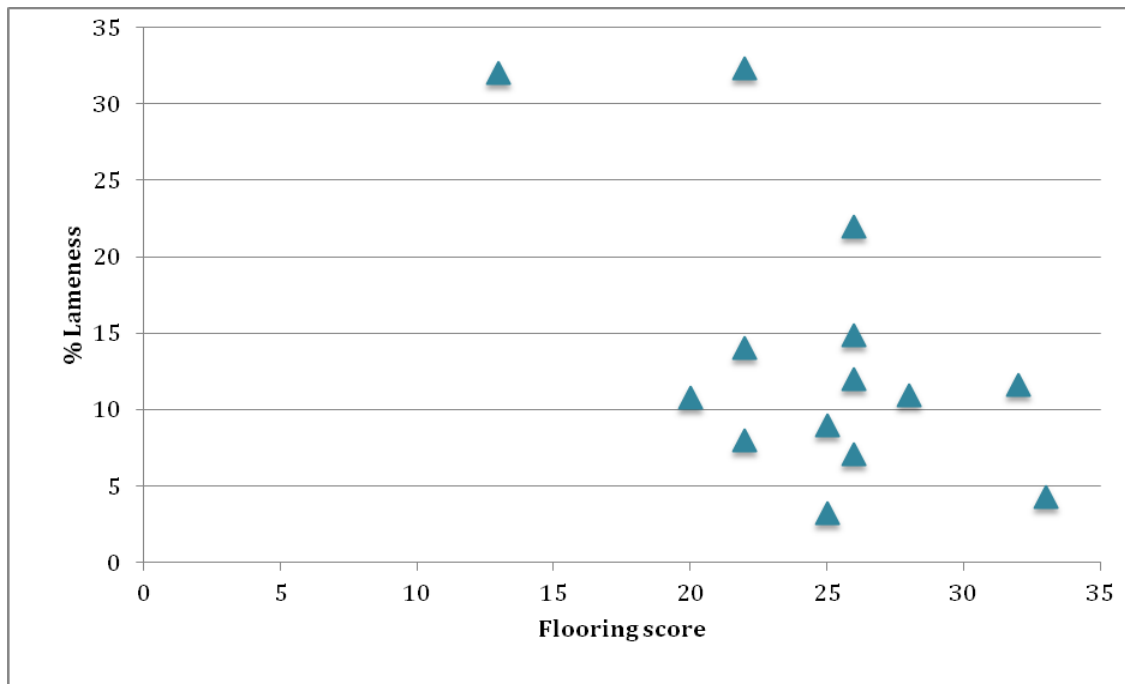


Figure 4: Lameness1 percentages vs Flooring of the Cow Comfort Score (R^2 0,270 , P 0,057)

2 out of 14 farms had rubber flooring in the walkways. One farm had rubber flooring on all flooring while the other farm only used rubber in the main walkways. The Lameness1 prevalence on those two farms was 40,2% and 37,8%, which is nearby the average lameness prevalence in the present study.

Feeding fence

The average height of the feeding fence was 145 centimetres, with the smallest feeding fence height of 135 centimetres. This feeding fence did lead to trauma at the neck of several cows. However, on the remaining 13 farms, the height of the feeding fence was correct for the cows. All 14 farms had headlocks. The number of places at the feeding fence did differ among farms, and was significantly correlated to Lameness1 (R^2 0,366/ P 0,022) and Lameness2 (R^2 0,300/ P 0,043).

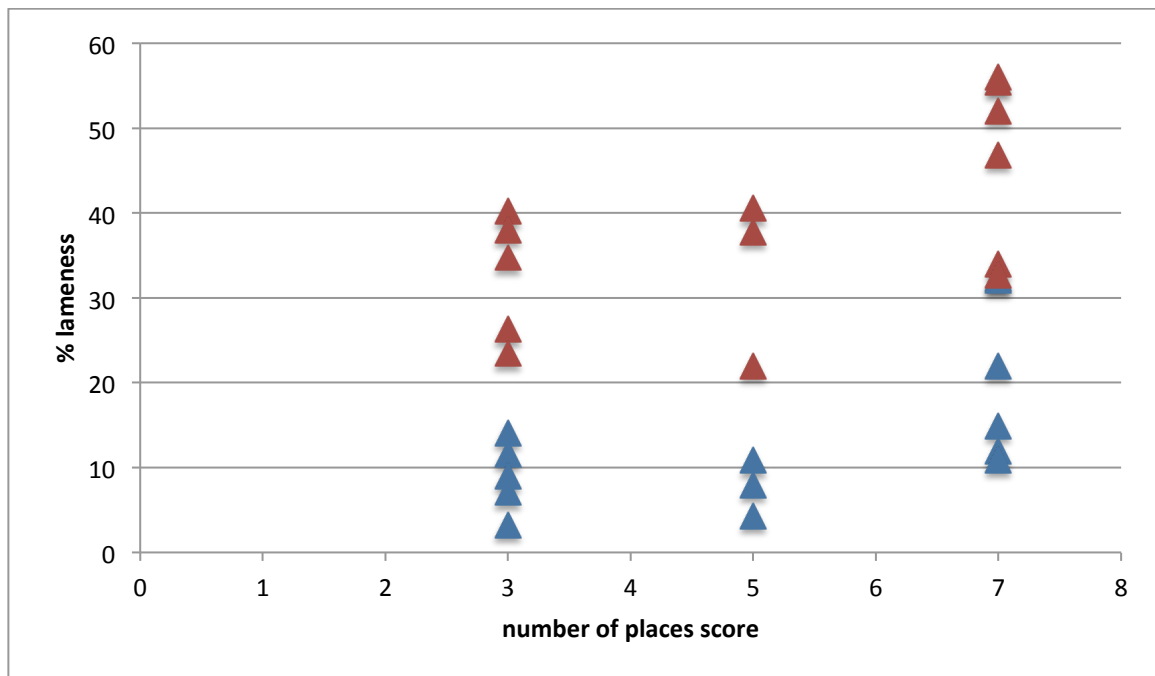


Figure 5: Lameness1 (blue) and Lameness2 (red) percentages vs Number of places at feeding fence

Walkways and alleys

The width of the alley behind the feeding fence was in 9/14 farms 3 meters. In 3/14 farms the width of the alley behind the feeding fence was 3,5 meter. 1/14 farm had a smaller alley of 285 centimetres. None of the farms met the requirements as described in the Cow Comfort Score with alleys behind the feeding fence of 4 meters.

Significant was the relation between the width of other alleys and lameness1 (R^2 0,331 / P 0,031) while lameness2 did not show causality (R^2 0,023 / P 0,601).

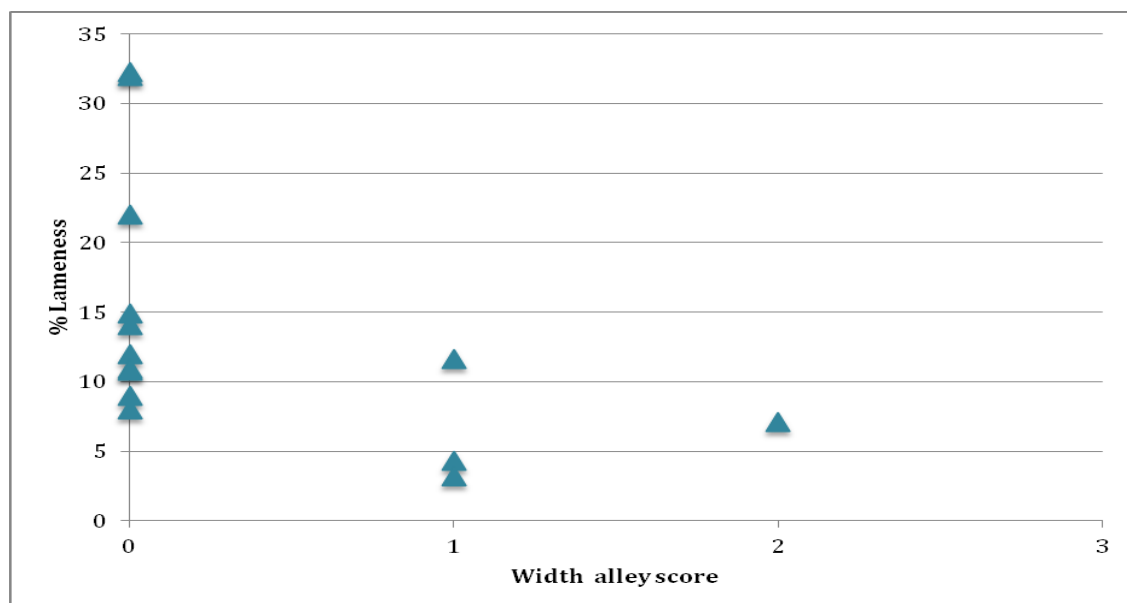


Figure 5: Lameness1 percentages vs Width alley score of Cow Comfort Score

Discussion

The lameness prevalence found in this study, 39%, is slightly higher than other studies conducted in for example England and Austria in which a lameness prevalence of 36,8%(range 0-73%) and 36% (range 0-77%) was found (Barker et al. 2010, Rouha-Mülleder et al. 2009). Those studies included a larger number of farms compared to the present study. In the present study, only 14 commercial dairy farms were visited, compared to 205 farms in England and 80 farms in Austria. Yet, the present study did include 1626 lactating dairy cows and the results of lameness prevalence are in line with other studies, indicating that the results of the present study are reliable.

The present study confirms the hypothesis that anatomical claw measurements are a good indicator for lameness. Gomez et al. (2003) found a correlation between claw score and lameness. That same study indicated the relation between dorsal border and diagonal measurements of the claw (Gómez, de Boer & van Eerdenburg 2003). In the present study no relation was found between the dorsal border of the claw and lameness, however, the length of the claw did correlate with lameness (R^2 0,376 / P 0,020). It is difficult to determine the cause-and-effect relationship between longer claws and lameness. Does lameness lead to inadequate footing and walking which results in a longer claw or does longer claws lead to more lameness? The amount of the claw that makes contact with the floor is important for developing claw lesions. Somers et al. (2004) stated that claw lesions are more likely to occur in the weight bearing area namely, bulb and sole. This is caused by the way that cows walk and the pressure is distributed over the claw. The pressure on the outside of the lateral claw (hind limb) increases at the heel strike, where the maximum pressure is on the bulb area.

Furthermore, the bulb area has softer horn than other parts of the claw (van der Tol et al. 2003). If the claws are longer it can mean less pressure per square centimetre, however, it can also indicate less frequent or incorrect hoof trimming that leads to more pressure on bulb and sole area. In the present study no data is collected of hoof trimming frequency and way of hoof trimming.

Substantial research is done on animal welfare and the society is demanding more and more on welfare quality. The Cow Comfort Score consists of maximal 500 points, representing maximal animal welfare. But it can also lead to a negative score of -500 points. With the adjusted chapter 'Animal health' the maximal Cow Comfort Score becomes 400 points. In the present study the average Cow Comfort Score was 262

points and only three farms got a Cow Comfort Score above 300 points. Although this study has a small sample size it does show that 50% of the included farms did not reach 250/500 points of the Cow Comfort Score (200/400 points for Adjusted Cow Comfort Score), meaning insufficient housing and compromised cow comfort. However, the median of 260 points in the present study is higher than 135 points that Van Eerdenburg et al. (2013) found in their study that included 48 Dutch farms. Both sample sizes are too small to draw conclusions considering all Dutch dairy farms. Therefore, further research, including more farms and more narrow selection criteria, is necessary to measure the general cow comfort on Dutch dairy farms.

The Cow Comfort Score is a good indicator when linked to the most common sign of pain and discomfort, namely lameness. With good recognisable lameness ('Lameness1') there is a significant relation (R^2 0,282/ P 0,051). It was expected that the relation between Cow Comfort Score and lameness was not very strong, since lameness has many risk factors. Those other risk factors were not standardised at the visited farms, so these factors cause more variation and interfere with the measured factors. However, even the small sample size and the fact that the present study was conducted under practice conditions, the relation between Cow Comfort Score and Lameness1 is significant. A possible explanation why Lameness2 did not correlate with the Cow Comfort Score is that causes and risk factors of mildly lame cows are different than that of severe lame cows. It is extensively discussed that besides housing there are other risk factors for developing lameness in dairy cows. For example: the impact of feeding, hormonal changes at calving and infectious agents (Cook, Nordlund 2009, Barker et al. 2010). Besides these factors, farm management also influences lameness. The perception of farmers on lameness varies. A recent study states that most farm managers underestimate lameness (Šárová et al. 2011). Farmers mostly recognize cows as lame when scoring 3 or higher according to the Sprecher locomotion scoring system. A possible explanation is that certain farmers are more actively focussing on lameness and trimming claws when cows are seen lame, thereby preventing that cows which are mildly lame become severely lame.

Lameness is considered a good welfare parameter since it is repeatable and reliably measurable in practice under farm circumstances. Besides, lameness is observed when lesions are found that cause hyperalgesia and, therefore, has a negative effect on animal welfare (Winckler, Willen 2001) In the present study, 14% of the assessed cows showed

severe lameness. It can be stated that there is a violation of animal welfare on these farms. This is an unwanted situation and needs societal, but more important, the farmers', attention and awareness.

It was expected that cubicle dimensions and the score of chapter 'Cubicles' would be a good predictor variable for lameness. In the present study, however, there was no significant relation, nor with individual items of the chapter 'Cubicles.' It is reported that lying comfort and dimensions of cubicles are important for welfare but also for the prevalence of lameness (Cook, Bennett & Nordlund 2004). Yet, in the present study on all the farms the cubicles were too small. So it is difficult to interpret on which farm the lying comfort was worse than on other farms. Decreased lying comfort results in the unwillingness of dairy cows to lie down. This results in over wearing the claws but also in less milk production. An indicator used in this study was 'Cows standing idle.' That was significant with Lameness1 but not with Lameness2. Cows that are standing idle increases when cows are hindered in their natural behaviour (for example due to overcrowding) and because of decreased lying comfort. Cook et al. (2005) described that their Cow Comfort index (CCI), which is the portion of cows that are lying down from all the cows that are touching a stall, increases when cows can lie on sand instead of mats. Also the standing time increases when bedding is insufficient. (Cook, Bennett & Nordlund 2005).

Optimally, the number of places at the feeding fence should be at least the same as the number of dairy cows in the herd. In the present study, it seems that overcrowding at the feeding fence is related to less lameness. This is remarkable considering existing reports. Overcrowding, higher stock density, leads to more inactive standing (Huzzey et al. 2006). Inactive standing leads to more claw lesions (Leonard, O'Connell & O'Farrell 1996). However, in the present study, the farms that have overcrowding at the feeding fence (score 3) are all farms with relative better floor quality. The average 'flooring' score of the farms with overcrowding was 27 compared to 23 of the farms that scored 7 points at the 'number of places at the feeding fence.' The 2 farms with rubber flooring in de walkways both do not have enough place at the feeding fence. Furthermore, the 3 farms that had the widest walkways behind the feeding fence (3,5 meters) were 3 farms that had overcrowding at the feeding fence (score 3). It seems that, due to the small sample size, certain variables do not show enough variability. This can also explain why 'flooring' did not show a significant relation with lameness, but only a trend ($P=0,057$).

Conclusion

The main aim of the present study was to relate prevalence of lameness to housing parameters and the general level of welfare using the Cow Comfort Score. Lameness (locomotion score 3 or higher) showed a significant relation. The cubicle dimensions itself did not lead to a significant relation, but combined with behaviour ('standing idle') and number of cubicles it did lead to a significant relation. Flooring shows a trend, especially when combining it with the width of the alleys.

Furthermore, the present study was used to determine if claw measures could predict the lameness percentages on a farm. It appeared to be that the longer the length of the claw, the higher the lameness prevalence was. It is possible that it is connected with the foot trimming frequency, but that needs further research.

Although the present study includes a small number of farms, only 14, it did show that overall cow comfort can be a good predictor for lameness. 39% as average lameness prevalence is high and a significant animal welfare problem that needs attention.

Further research must point out whether the lameness prevalence is a general problem in dairy cattle.

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Appendices

Appendix 1: Cow Comfort Score

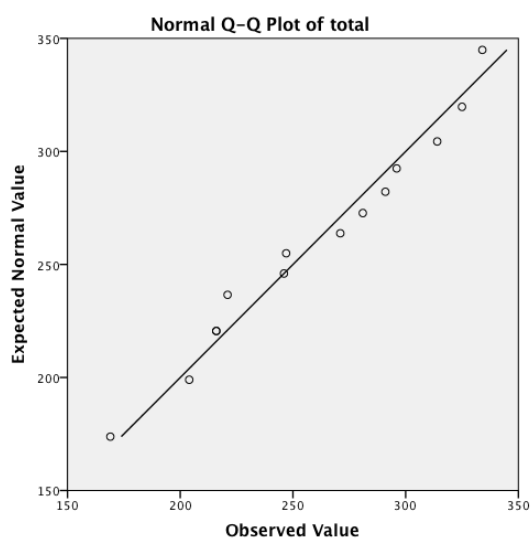
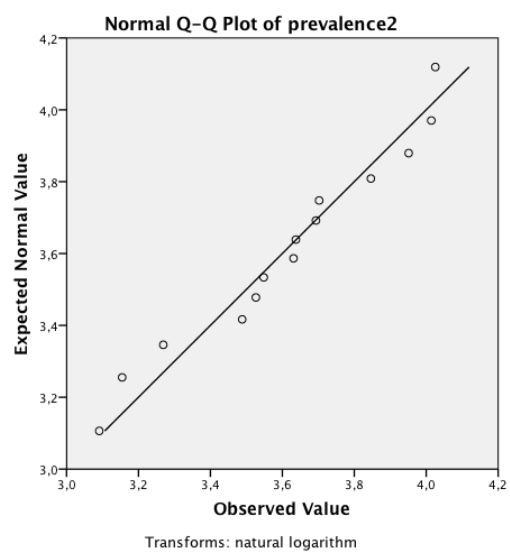
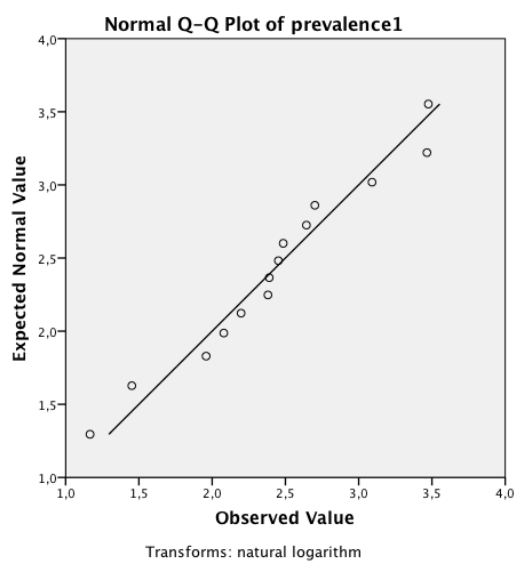
	Minimum	Maximum	points
General	10	20	
- Number of cows standing idle		0 (-100)	
- Fear behaviour		5	
- Stretching when raising from cubicle		3	
- Tail is hanging straight and relaxed		3	
- Bellowing		4	
- Cows sleeping in walkways		5 (- 10)	
- Noise (environmental)		0 (-5)	
Light	5	25	
- Sufficient light in the barn		10	
- Period of light > 15 hr		5	
- Period of dark > 6 hr		10	
Ventilation	30	50	
- It smells fresh (between the animals)		5	
- Cobwebs		10	
- Condense / mold		10	
- Barn temperature		10	
- Dead spaces		5	
- Draft		10	
Cubicles / Free stalls	40	70	
- Cows are clean		5	
- Bedding is made of inorganic material		5	
- Bedding is soft		10 (-10)	
- Bedding is clean and dry		10	
- Stall surface is under a slight angle		5	
- Bedding is flat		5 (-5)	
- Neck rail		5	
- Lunge space		10	
- Length / width of the stall		10	
- Brisket board		5	
- Number		0 (-10)	

Floor	20	45	
- Slipperiness		10	
- Loose / unequal slats		10	
- Rubber		10	
- Walking		10	
- Cleanliness		5	
Feeding fence	6	15	
- Headlocks		5	
- Height		3	
- Number of places		7	
- Contamination		(-3)	
Concentrate dispenser	0	7	
- Number		5	
- Type		2	
Water	15	25	
- Number of places		10	
- Type of waterer		5	
- Cleanliness		5	
- Temperature		5	
Waiting room and milking parlor	2	5	
Behaviour		3	
Time		2	
Walkways and alleys	3	5	
Width of the alley behind the feeding fence		2 (-2)	
Width other walkways		2	
Sufficient passages		1	
Miscellaneous	10	40	
Maternity pen		3	
Sick bay		2	
Access to pasture / outside paddock		20	
Is there a mechanical brush?		15	

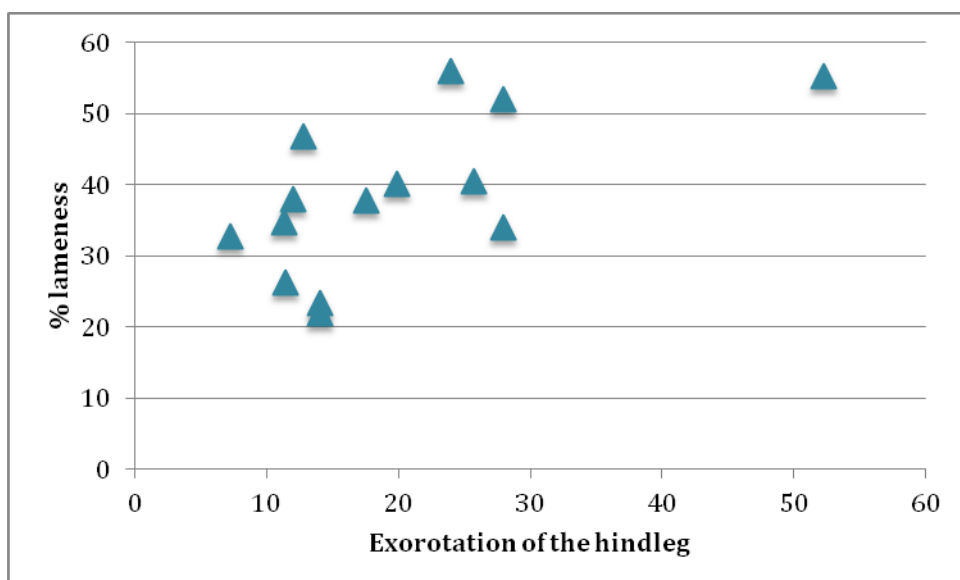
Animal (health + feeding)	100	200	
- Hair		5	
- Lameness		25 (-25)	
- Hocks		20 (-60)	
- Carpus		20 (-60)	
- Claws		20	
- Mastitis		15 (-15)	
- Abomasal dislocation		10 (-15)	
- Filling of the rumen		5 (-10)	
- Milking fever		5 (-10)	
- Acetonaemia		5 (-15)	
- BCS		15	
- Fat %		15	
- Fertility		25 (-10)	
- Calving		15	

Table 1.1: Cow Comfort Score according to Van Eerdenburg et al. (2013)

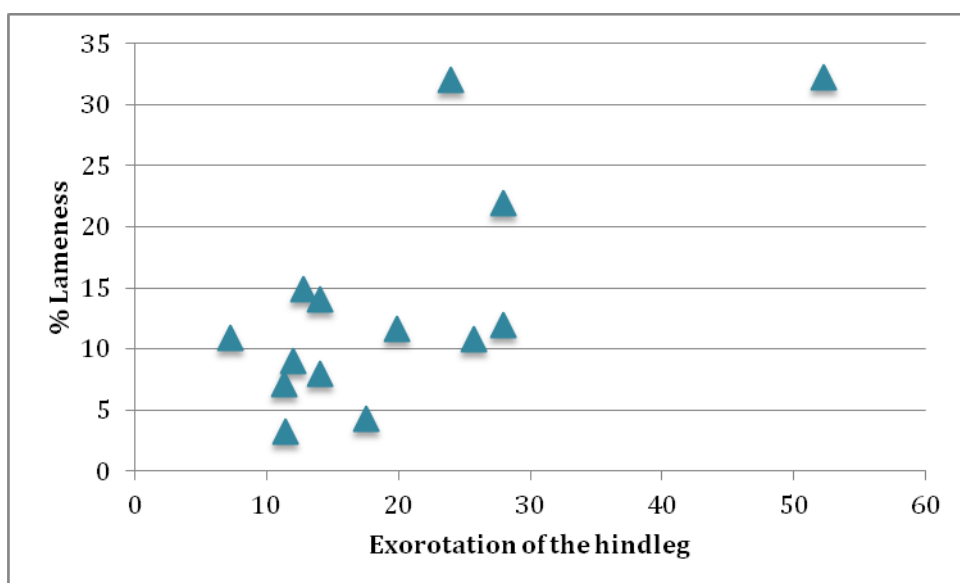
Appendix 2: Q-Q plot



Appendix 3: lameness and exorotation of the hindleg



3.1 Lameness2 vs prevalence exorotation of the hindleg >1



3.2 Lameness1 vs prevalence exorotation of the hindleg >1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,714 ^a	,510	,421	,21863

a. Predictors: (Constant), standscore, length.claw

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,547	2	,273	5,717	,020 ^b
	Residual	,526	11	,048		
	Total	1,072	13			

a. Dependent Variable: log1lameness

b. Predictors: (Constant), standscore, length.claw

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-4,074	2,955		-1,379	,195
	length.claw	,230	,141	,383	1,632	,131
	standscore	,011	,006	,459	1,956	,076

a. Dependent Variable: log1lameness

3.3 In this multiregression the Length of the claw and the exorotation of the hindleg are combined as predictor variables for lameness

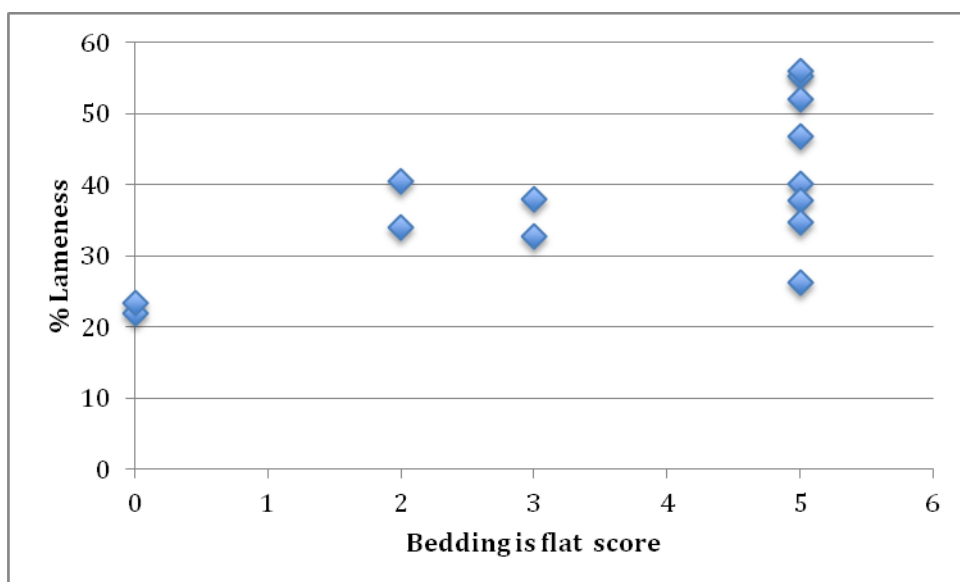
Appendix 4: summary regression lameness and items cow comfort score

	log lameness1		log lameness2	
general	R square	P-value	R square	P-value
number of cows standing idle	0,490	*0,005	0,176	0,135
fear behaviour	0,010	0,736	0,002	0,884
stretching	0,084	0,314	0,108	0,252
tail movement	0,252	^0,067	0,163	0,152
bellowing	0,100	0,270	0,074	0,346
sleepers in walkways	0,001	0,928	0,007	0,776
noise	No variation		No variation	
light				
sufficient light in barm	0,000	0,968	0,001	0,899
period of light	0,000	0,963	0,044	0,472
period of dark	0,008	0,757	0,083	0,318
ventilation				
it smells fresh	0,128	0,210	0,092	0,291
cobwebs	0,037	0,511	0,041	0,488
condens	0,167	0,164	0,155	0,163
barn temperature	0,058	0,408	0,018	0,647
dead spaces	0,166	0,148	0,013	0,699
draft	0,005	0,810	0,064	0,382
cubicles				
cows are clean	0,023	0,601	0,021	0,622
type of bedding	No variation		No variation	
bedding is soft	0,001	0,937	0,138	0,190
bedding is clean	0,082	0,320	0,047	0,457
stall surface	0,003	0,857	0,002	0,881
bedding is flat	0,004	0,821	0,478	*0,006
neck rail	0,150	0,172	0,143	0,182
lung space	0,210	0,099	0,126	0,212
length/width of stall	0,141	0,187	0,013	0,699
briquet board	0,003	0,846	0,000	0,943
number	0,173	0,139	0,030	0,556
flooring				
slipperiness	0,252	^0,067	0,000	0,942
loose/unequal slats	0,132	0,202	0,219	0,094
rubber	0,092	0,293	0,005	0,810
walking	0,245	0,072	0,002	0,865
cleanliness	0,019	0,636	0,038	0,503
feeding fence				
headlocks	No variation		No variation	
height	0,004	0,836	0,180	0,131
number of places	0,366	*0,022	0,300	*0,043
contamination	No variation		No variation	
concentrate dispenser				
number	0,001	0,908	0,008	0,766

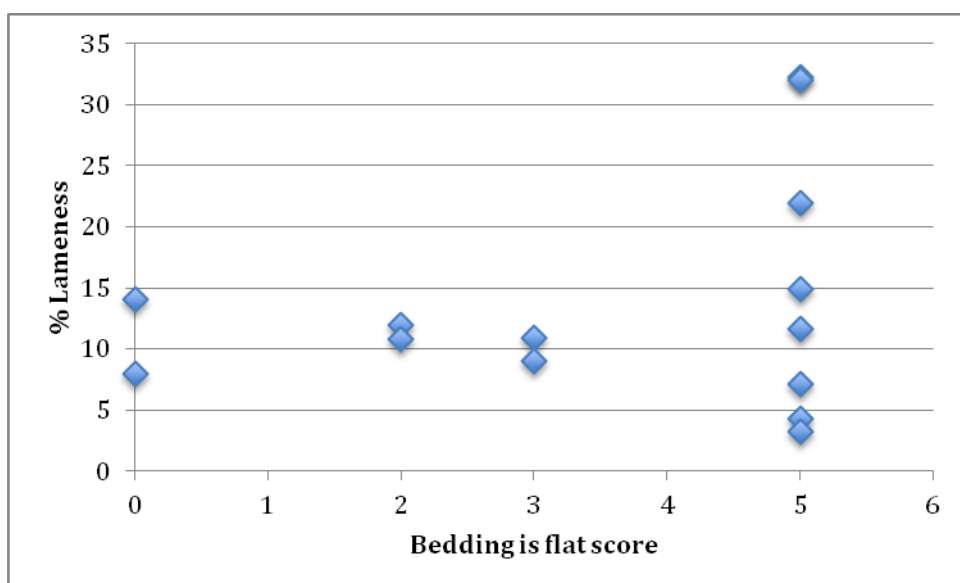
type	0,063	0,385	0,079	0,331
water				
number of places	0,030	0,552	0,054	0,426
type of water	0,006	0,792	0,002	0,883
cleanliness	0,022	0,616	0,034	0,525
temperature	0,200	0,109	0,100	0,272
waiting room and milking parlor				
behaviour	0,004	0,825	0,020	0,629
time	0,443	*0,009	0,010	0,738
walkways and alleys				
width of the alleys behind the feeding fence	0,050	0,442	0,000	0,971
width other walkways	0,331	*0,031	0,023	0,601
sufficient passages	0,084	0,314	0,108	0,252
miscellaneous				
maternity pen	0,003	0,846	0,000	0,954
sick bay	0,084	0,314	0,108	0,252
access to pasture	0,102	0,267	0,105	0,259
mechanical brush	0,095	0,284	0,114	0,237
animal health and feeding				
hair	0,082	0,321	0,023	0,604
lameness	0,660	*0,000	0,541	*0,003
hocks	0,104	0,260	0,373	*0,020
carpus	0,189	0,121	0,411	*0,013
claws	0,331	*0,031	0,524	*0,003
mastitis	0,331	*0,038	0,154	0,165
LDL	0,152	0,168	0,001	0,909
filling of the rumen	0,027	0,575	0,008	0,755
milking fever	0,163	0,152	0,007	0,780
acetonaemia	0,060	0,397	0,025	0,590
BCS	0,044	0,470	0,062	0,392
fat%	0,414	*0,013	0,095	0,284
fertility	0,006	0,785	0,025	0,587
calving	0,041	0,489	0,073	0,349

Green items are the individual items that are included in the Adjusted animal health.

Appendix 5: Cubicles



5.1 Lameness2 vs Bedding is flat score of Cow Comfort Score



5.2 Lameness1 vs Bedding is flat score of the Cow Comfort Score

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,938 ^a	,880	,805	,05682

a. Predictors: (Constant), number.of.cubicles, standing.idle, length.width, flat, lungespace

ANOVA^a

Model	Sum of Squares	df	Mean Square	F	Sig.
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1	Regression	,190	5	,038	11,761	,002 ^b
	Residual	,026	8	,003		
	Total	,216	13			

a. Dependent Variable: log2lameness

b. Predictors: (Constant), number.of.cubicles, standing.idle, length.width, flat, lungespace

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1,392	,073		18,953	,000
	standing.idle	-,007	,003	-,351	-2,686	,028
	flat	,062	,015	,915	4,055	,004
	length.width	-,006	,024	-,083	-,262	,800
	lungespace	-,009	,024	-,102	-,366	,724
	number.of.cubicles	,027	,010	,430	2,786	,024

a. Dependent Variable: log2lameness

5.3 In this multiregression 5 variables are combined as predictor variables for lameness2