Genetic parameters for lameness and claw and leg diseases in dairy cows

A. Weber,^{*1} E. Stamer,[†] W. Junge,^{*} and G. Thaller^{*}

^{*}Institute of Animal Breeding and Husbandry, Christian-Albrechts-University, D-24098 Kiel, Germany

[†]TiDa Tier und Daten GmbH, D-24259 Westensee, Germany

ABSTRACT

Lameness in dairy cows is a serious welfare and economic problem in dairy production. The majority of all lameness cases seem to stem from claw and leg diseases. Indirect selection on claw health potentially might be feasible with lameness as indicator trait. Therefore, the genetic parameters for the 2 traits were estimated by applying both linear and threshold models. In addition, the impact of environmental effects, parity, and stage of lactation was analyzed. In total, 8,299 locomotion scores (1–5) of 326 dairy cows and 708 claw and leg disease diagnoses or treatments of 335 dairy cows from the dairy research farm Karkendamm (Institute of Animal Breeding and Husbandry, Christian-Albrechts-University, Kiel, Germany) were analyzed. Lameness was defined by a locomotion score of ≥ 3 . Days in milk were limited to the range of 10 to 350 d. To quantify the effect of the claw disease digital dermatitis, a second data set without this disease was built; 52.8 and 36.4% (without digital dermatitis) of the cows were treated at least once; 47.2% of the cows were clinically lame at least at one time. Genetic parameters were estimated bivariately using the average information restricted maximum likelihood procedure as implemented in the DMU software package. The heritability estimates derived from the threshold model were about twice as large as the values based on the linear model. For lameness, the threshold heritability increased from 0.15 to 0.22 and decreased for the diseases from 0.24 to 0.22 after exclusion of digital dermatitis. The genetic correlations were high and even increased from 0.60 to 0.72 after the exclusion of digital dermatitis, which suggests that lameness (locomotion score) seems to be a good indicator for claw and leg diseases. Digital dermatitis seems to affect the mobility of the dairy cow less strongly than other claw and leg diseases.

Key words: dairy cow, locomotion score, lameness, claw and leg diseases

INTRODUCTION

Lameness in dairy cows is one of the major animal welfare issues in dairy production. It is a painful condition and causes economic losses through decreased milk production, impaired reproductive performance, and involuntary culling (Kossaibati and Esslemont, 1997). In German herds, lameness (claw and leg lesions) is the third main reason for early culling after mastitis and infertility problems. Annual statistics published by the German Cattle Breeders Federation (Bonn, Germany) show that the percentage of cullings because of feet and leg disorders among all cullings increased from 4.40 (1980) to 10.40% (2009) in the last 30 yr (ADR, 1980–2009). The majority of all lameness cases seemed to be caused by claw and leg lesions; Murray et al. (1996) quantified this amount at about 90%.

Much of the variability in foot diseases is associated with environmental factors, such as management and housing. Nevertheless, a few studies have found a genetic effect on such a trait (Koenig et al., 2005; Swalve et al., 2008; van der Linde et al., 2010). Therefore, apart from improvement of the environmental effects, claw health may be improved through selection. Direct selection on claw diseases is difficult because detailed inspection of the claws can be expensive and time intensive. Successful indirect selection demands a high genetic correlation between the indicator trait and claw health and the trait has to be heritable. Such a trait could be lameness recorded as an indicator trait for claw diseases. Controlling and examination of lameness at a herd level is potentially possible with a well-established locomotion scoring system. Several approaches were developed in the last 23 yr (Manson and Leaver, 1989; Sprecher et al., 1997). Thus, this trait might be more easily and inexpensively assessed than specific claw lesions (Boettcher et al., 1998). A few studies have reported heritabilities for locomotion, which is being used as an additional conformation trait in the type classification of Holstein-Friesian heifers (van der Waaij et al., 2005; Laursen et al., 2009; van der Linde et al., 2010). In contrast to the genetic parameters for claw health and locomotion, the parameters for lameness have not been well investigated.

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¹Corresponding author: aweber@tierzucht.uni-kiel.de

Thus, the first objective of this study was to examine the impact of the environmental effects, such as parity or stage of lactation, on lameness and claw and leg diseases. Then, taking the relevant fixed effects into consideration, the genetic parameters were estimated by applying both linear and threshold models.

MATERIALS AND METHODS

Data

Locomotion scores were recorded between September 2010 and February 2012 on the dairy research farm Karkendamm of the Institute of Animal Breeding and Husbandry, Christian-Albrechts-University Kiel (Germany). According to the system of Sprecher et al. (1997), 326 lactating Holstein-Friesian cows (primiparous and multiparous) were examined weekly for lameness (locomotion score) by one classifier. This system emphasizes the leg placement and back posture of the dairy cows and is expressed by 5 possible scores (1 = normal gait, 2 = mildly lame, 3 = moderately lame, 4 = lame, and 5 = severely lame). Locomotion was scored while the cows were standing or walking on the concrete slatted passageways at the feeding bunk or between the cubicles on 1 of the 2 concrete slatted floor systems. Cows in straw and the selection yard were not assessed. Before the start of the study period, all animals were examined weekly for 2 mo to train the judge in the procedure of scoring locomotion. As the emphasis of this study was mainly on the investigation of lameness in dairy cows and due to the low number of the more extreme scores (scores 4 and 5), the locomotion scores were dichotomized, using 3 as the cut-off. As shown in Figure 1, in almost 16% of the locomotion scores (3 to 5) cows were classified as lame. For further analysis, clinically lame cows were coded as 1 (score ≥ 3). If the locomotion was normal (scores 1 and 2), the value was set to 0.

In the same observation period as scoring locomotion, all claw and leg diagnoses and treatments were recorded by a veterinarian or farm staff. On the research farm, the claws of the animals were trimmed routinely until 100 d postpartum and before the dry period by one claw trimmer (farm staff). In addition to this routine, cows recognized as lame by locomotion scoring or farm staff were examined. All in all, 8 different claw and leg disorders were diagnosed and treated (Table 1). The main claw disease was sole ulcer with a frequency of 24%, followed by digital dermatitis with a frequency of about 22%. The frequency of leg disease was small (slightly less than 7%). The number of claw and leg diseases decreased from 771 to 708 in the final data set due to the restriction of being within

Table 1. Frequencies (%) of the recorded claw and leg diseases

Diagnosis	Absolute frequency	Relative frequency
Sole ulcer	183	24
Digital dermatitis	167	22
Interdigital hyperplasia	148	19
Interdigital necrobacillosis	127	17
White line disease	61	8
Leg lesions (e.g., hock swelling)	51	7
Double sole	27	4
Undefined injuries	7	1
Total	771	

10 and 350 DIM. For definition of the trait claw and leg diseases, each day with at least 1 treatment was coded as 1. Additionally, the following 8 DIM were also coded as 1. The 8-d period was chosen because claw and leg diseases seemed to affect the cows for at least 1 wk (Buttchereit et al., 2012). All other days were classified as healthy (coded as 0). Days in milk were limited to the range of 10 to 350 d because of the small number of cows in the first days postpartum and above 350 lactation days. To quantify the effect of the claw disease digital dermatitis, a second data set without this disease was built.

Table 2 summarizes the number of affected cows and the number of days coded as 1 for claw and leg diseases and lameness (score ≥ 3). In total, 52.8 and 36.4% (without digital dermatitis) of the 335 examined cows were treated at least once because of one or more claw and leg diseases, and 47.2% of the 326 rated cows were clinically lame at least at one time in the observation period.

Figure 1. Frequencies of locomotion scores.

Table 2. Frequencies of claw and leg diseases (with and without digital dermatitis) and lameness (score ≥3)

Trait	Lactation period (d)	Cow days		Cows (lactations)	
		Total	Affected (%)	Total	Affected (%)
Claw and leg diseases	10 to 350	73,433	6.7	335 (420)	52.8 (60.0)
Claw and leg diseases without digital dermatitis	10 to 350	73,433	5.0	335 (420)	36.4 (32.9)
Lameness (score ≥3)	10 to 350	8,299	15.4	326 (404)	47.2 (43.3)

Statistical Analysis

The model fitting was done with PROC GENMOD using the probit link function of the SAS package (SAS Institute, 2008). For all model runs, fixed effects with only one value (0 or 1) were added to neighboring classes to avoid extreme categories (Hoeschele and Tier, 1995; Luo et al., 2001). A model with the fixed effects test day and 21 different combinations of lactation stage and lactation number as well as their interactions were tested. Evaluation of goodness of fit of different models for locomotion score and claw and leg diseases was carried out using the corrected Akaike information criterion (**AICC**; Burnham and Anderson, 1998) and the Bayesian information criterion (**BIC**; Schwarz, 1978). The model that minimizes AICC or BIC is superior, but if AICC or BIC are close, the simpler model is generally considered preferable (Littell et al., 2006). Based on the results of the model fitting, the following threshold was used for the 3 traits claw and leg diseases, claw and leg diseases without digital dermatitis, and lameness (score ≥3) to test and to describe the fixed effects:

$$E[\pi_{ijkl}] = \Phi(TD_i + LNO_j + LS_{jk} + cow_l),$$

where $E[\pi_{ijkl}]$ = expected probability for occurrence of claw and leg diseases or lameness (score ≥3); Φ = cumulative probability of standard normal distribution; TD_i = fixed effect of i th test day ($i = 1$ to 507 for claw and leg diseases, $i = 1$ to 504 for claw and leg diseases without digital dermatitis, and $i = 1$ to 69 for lameness); LNO_j = fixed effect of the j th lactation number ($j = 1, 2$, or ≥ 3); LS_{jk} = fixed effect of the k th lactation stage (10–50, 51–100, 101–150, 151–200, 201–250, 251–300, or 301–350) within the j th lactation number; and cow_l = random effect of the l th cow ($l = 1$ to 335 for claw and leg diseases, $l = 1$ to 335 for claw and leg diseases without digital dermatitis, and $l = 1$ to 326 for lameness).

The models were analyzed using PROC GLIMMIX in SAS with the residual marginal pseudo-likelihood (RMPL) method. The significance of differences between least squared means was adjusted with the Bonferroni correction (SAS Institute, 2008).

Genetic parameters for claw and leg diseases (with and without digital dermatitis) and lameness were es-

timated using the average information (**AI**) restricted maximum likelihood procedure as implemented in the DMU software package (version 6, release 5.0; Madsen and Jensen, 2010). For these estimations, the above-described threshold model included the random permanent environmental effect of the cow and the additive genetic effect of the animal instead of the random effect of the cow. Pedigree information contained sires and dams 3 generations back, so in total, 1,649 animals were in the pedigree file. Heritabilities and genetic correlations between claw and leg diseases (with and without digital dermatitis) and lameness were estimated bivariate with threshold models as well as with the following linear model:

$$Y_{ijklmn} = \mu + TD_i + LNO_j + LS_{jk} + p_l + a_m + e_{ijklmn},$$

where Y_{ijklmn} = observation of claw and leg diseases or lameness, μ = overall mean, p_l = random permanent environmental effect of the l th cow ($l = 1$ to 335 for claw and leg diseases, $l = 1$ to 335 for claw and leg diseases without digital dermatitis, and $l = 1$ to 326 for lameness), a_m = random additive genetic effect of the m th animal ($m = 1$ to 1,649), and e_{ijklmn} = random residual effect.

RESULTS

Figure 2 shows the prevalence of claw and leg diseases and lameness (score ≥3) during 10 to 350 DIM. The trajectory of the claw and leg diseases showed a peak at the beginning of the lactation, whereas the frequency of lameness remained at a constant low level during the same time period. After the first 2 lactation months the prevalence of both traits persisted at a constant height.

In the first analysis, a generalized linear model was used to investigate the fixed (environmental) effects on lameness and claw and leg diseases. According to the results of the F -tests, all fixed effects [test day and lactation number (1, 2, and ≥3)] included in the final model and the interaction between lactation number and lactation stage had a highly significant effect ($P < 0.0001$) on the probability of incidence of lameness and claw and leg diseases.

The covariance parameter of the random effect cow and the scale parameter for claw and leg diseases (with

Figure 2. Prevalence of claw and leg diseases and lameness (score ≥ 3) during 10 to 350 DIM.

and without digital dermatitis) and lameness (score ≥ 3) are given in Table 3. The covariance parameter estimate for claw and leg diseases increased from 0.4985 to 0.6719 with almost constant scale parameter after the claw disease digital dermatitis was excluded from the data set. This result indicates that the frequency of digital dermatitis was largely influenced by environmental effects such as farm management. For lameness, the covariance parameter was quite high compared with the parameters for the claw and leg diseases.

The probability of lameness (score ≥ 3) increased clearly with increasing lactation number (parity; Figure 3). For the diseases, the pattern was not so clear. The probability of claw and leg diseases decreased slightly from the first to the second lactation. After the exclusion of digital dermatitis the likelihood for the occurrence of claw and leg diseases declined for the first 2 parities, whereas the probability for older cows increased slightly. For cows with at least 3 lactations, lameness and claw and leg diseases were more common.

In the course of lactation, the probability of lameness increased until 150 DIM and decreased shortly after for both primiparous cows and cows with at least 3 lactations (Figure 4). In contrast, in second-parity cows' risk of lameness seemed to be highest around 250 DIM. Cows in the third or higher parities were more susceptible for lameness than younger cows (Figure 4).

In contrast to lameness, the probability for claw and leg diseases was highest in early lactation (Figure 5). For first-parity cows, the trajectory declined gradually

Figure 3. Probability of lameness (score ≥ 3) and claw and leg diseases with and without digital dermatitis depending on lactation number (F -test; $P < 0.0001$; LSM).

with increasing stage of lactation. The probability for cows with at least 3 lactations also indicated a declining trend but with an increasing probability around 250 DIM. For second-parity cows, the probability of the occurrence of claw and leg diseases did not show a clear pattern. But the trajectory indicated rather an increasing than a decreasing trend. At the end of lactation, all observed parities were on the same level. Older cows seemed to be more vulnerable to claw and leg diseases.

In the case of claw and leg diseases without digital dermatitis, the trajectory for second-parity and older cows was similar to that with digital dermatitis (Figure 5). Just the height changed; for cows in the second lactation, the means were marginally lower and for the older cows marginally higher. The figure reflects the fact that the effect of the exclusion of the claw disease digital dermatitis was highest for primiparous cows. The trajectory for this group of cows did not show a strong peak at the beginning of lactation and the course remained on a constant level during lactation.

Heritability estimates for lameness ($h^2 = 0.08$) were higher than for claw and leg diseases ($h^2 = 0.02$; Table 4). The estimates for the heritabilities based on the linear model did not change after the exclusion of the claw disease digital dermatitis. In the threshold model analysis, compared with the estimates of the linear model, the heritabilities were about twice as large for lameness and even higher for claw and leg diseases.

Table 3. Covariance parameter estimates of the random effect cow (σ_c^2), with standard errors in parentheses and estimates of the scale parameter ($\emptyset$) for claw and leg diseases (with and without digital dermatitis) and lameness (score ≥ 3)

Trait	σ_c^2	$\emptyset^1$
Claw and leg diseases	0.4985 (0.043)	0.95
Claw and leg diseases without digital dermatitis	0.6719 (0.056)	0.96
Lameness (score ≥ 3)	0.9054 (0.096)	0.59

¹Ratio of the generalized χ^2 statistic and its degrees of freedom.

Table 4. Additive genetic variance (σ_a^2), permanent environmental variance (σ_{pe}^2), residual variance (σ_e^2), heritability estimates (h^2) for lameness (score ≥ 3), and claw and leg diseases (with and without digital dermatitis) and genetic correlations (r_g) from different models¹

Traits in bivariate model ²	σ_a^2	σ_{pe}^2	σ_e^2	h^2	r_g
Linear					
Lameness (score ≥ 3)	0.011	0.052	0.074	0.081	0.939
Claw and leg diseases	0.001	0.007	0.055	0.019	
Lameness (score ≥ 3)	0.011	0.048	0.074	0.085	0.951
Claw and leg diseases without digital dermatitis	0.001	0.005	0.041	0.021	
Threshold					
Lameness (score ≥ 3)	0.432	1.799	0.610	0.152	0.597
Claw and leg diseases	0.419	0.652	0.681	0.239	
Lameness (score ≥ 3)	0.550	1.401	0.604	0.215	0.716
Claw and leg diseases without digital dermatitis	0.398	0.923	0.510	0.218	

¹Standard errors for heritabilities: 0.02 to 0.15; standard errors for genetic correlations: 0.27 to 0.31.

²For each model (linear and threshold), 2 separate bivariate analyses were conducted. First, lameness and claw and leg diseases and second, lameness and claw and leg diseases without digital dermatitis. Lameness was the same trait in each of both analyses but the results for lameness are different because they depend also on the second trait, which was here analyzed simultaneously.

After omitting digital dermatitis, the threshold heritability for lameness increased from 0.15 to 0.22 and decreased from 0.24 to 0.22 for the diseases.

The genetic correlations between lameness and claw and leg diseases derived from the linear model were higher than from the threshold model. The estimates ranged from 0.60 to 0.72 (threshold model) and from 0.94 to 0.95 (linear model).

DISCUSSION

Frequencies of Lameness (Score ≥ 3) and Claw and Leg Diseases

In our study, the lameness rate (ca. 15%) agrees to a reasonable extent with the result of Frankena et al. (2009; ca. 23%). Of the 326 examined cows, 47.2% were lame (score ≥ 3) at least once. This figure is in accordance with the prevalence in the study of Frankena et al. (2009); those authors found that almost 37% of the observed animals were lame at least once during their examination. In contrast, Sogstad et al. (2005b,

2012) and Manske et al. (2002) reported obviously lower values, which may have resulted from different examination environments. Further reasons for the large variability in reported lameness occurrence might be different scoring methods and different sources of lameness data. Lower lameness incidence could also be associated with breed, small herd sizes, and low milk yield (Sogstad et al., 2012).

In this study, we found that 52.8 and 36.4% (without digital dermatitis) of the 335 examined cows were affected at least once by one or more claw or leg diseases. Our findings are quite low compared with the results from other studies. In a Dutch study, 69% of the animals from different lactations suffered from at least

Figure 4. Probability of lameness (locomotion score ≥ 3) depending on lactation number within lactation stage (F -test; $P < 0.0001$; LSM).

Figure 5. Probability of claw and leg diseases (with and without digital dermatitis) depending on lactation number within lactation stage (F -test; $P < 0.0001$; LSM).

one claw disease (van der Linde et al., 2010). Although their analysis was also based on cows that could have repeated observations within lactation as well as across lactations, the study period was clearly different, which makes the comparison of the results difficult. A rather low rate of affected animals (40%) was reported by Buch et al. (2011). In this Swedish study, only claw and leg diseases from the first claw trimming after first calving were taken into account. The authors suggested that claw diseases such as laminitis, sole hemorrhages, and sole ulcers would not occur at that time because they are of metabolic origin (Buch et al., 2011). Besides the disagreement in the number of recordings, their study also is distinguished by the time of claw trimming.

The decreased rate of affected cows after nonconsideration of digital dermatitis cases as well as the high frequency of the disease indicates that digital dermatitis seems to be a herd problem. Several animals were only affected by digital dermatitis (Table 2), which was the second-most-frequent disease (22%) after sole ulcer with a frequency of 24%. The frequency of leg diseases was small (almost 7%). Compared with the frequencies of claw and leg diseases published by other authors, the disease pattern presented in our study was rather specific. As shown in several studies, sole hemorrhage was the most prominent claw disease, whereas laminitis or sole hemorrhages were not mentioned in our investigation (Sogstad et al., 2005a,b; van der Waaij et al., 2005; van der Linde et al., 2010). Individual cases of mild forms of hemorrhages in the horn of the sole were measured but these cases were attached to the disease sole ulcer. As Bergsten (2003) indicated, minor hemorrhages in the horn of the sole reflect the early phase of laminitis and most commonly occur in regions that are the rear part of the claw bone and are recognized as the typical sole ulcer site.

The comparison of the frequencies of claw and leg diseases is also difficult because categorizing and diagnosing claw and leg lesions, methods of data recording, observation period, and data sources often differ among the published studies, which might cause differences in frequencies (Sogstad et al., 2005b).

The trajectory of the frequencies of claw and leg diseases showed a peak at the beginning of the lactation, which might be a result of the routine hoof trimming at that time (Figure 2). The lower constant level in the frequency of lameness could result from the fact that only a small number of early lactation cows could be examined at that time. To ensure particular supervision, early lactation cows were housed in a separated barn area. Due to the constructional circumstances of this barn, the lameness status of the cows could not be classified.

Probability of Lameness (Score ≥ 3) and Claw and Leg Diseases (Without Digital Dermatitis) Depending on Lactation Number

The incidence of lameness increased with increasing parity (Figure 3) as also shown by Rowlands et al. (1985), Groehn et al. (1992), and Boettcher et al. (1998). In a prospective cohort study by Groehn et al. (1992), more than a 30% risk of becoming lame exists for a 1-yr increase in age. Alban (1995) found the highest risk for lameness in Danish dairy heifers and fourth-parity cows. The high hazard in first-parity cows might originate from the rapid environmental and metabolic shifts that are associated with first calving (Alban, 1995).

The probability of claw and leg diseases did not show a clear increasing trend but the highest probability was found in cows with at least 3 parities. After omission of digital dermatitis, the probability of claw and leg diseases for the first 2 parity classes decreased and increased slightly for cows in higher parities. The occurrence of claw and leg diseases related to the parity is strongly dependent on the specific disease. Rowlands et al. (1985) have shown that the incidence of white line disease and sole ulcer and, to a lesser degree, under-run heel increased with age. The incidence for foul in the foot and leg lesions only showed marginal change with parity. Koenig et al. (2005) reported significant influences of parity on wall disorders and sole ulcers, but no effect was observed on digital dermatitis and interdigital hyperplasia. Furthermore, the authors indicated that the susceptibility to digital dermatitis was slightly higher for primiparous cows than for cows in higher parities (13.9 vs. 12.5%), which is comparable with our observations. In addition, several authors have shown that the probability for occurrence of digital dermatitis generally decreased with increasing parity. A cause for the susceptibility of first-parity cows to digital dermatitis could be the changes in nutrition, metabolism, and environment before and after calving. The decreased risk of digital dermatitis with increasing age might be result from the rising immunity of older cows (Somers et al., 2005; Holzhauer et al., 2006).

A reason for the higher risk of claw and leg diseases and lameness in older cows could be the fact that cows in higher parities have been subject to greater effects of age, wear, and stress than younger cows (Boettcher et al., 1998). Boelling and Pollott (1998a) noted that the impairment of mobility in older cows resulted from an alteration in body conformation (i.e., bulky udder and sickled rear leg). The authors found that a high locomotion score was associated phenotypically with a big udder and sickled legs. Mature cows with bulky udder

develop a splay-legged gait and this has been attributed to the fact that the rear leg had to elude the udder by describing a circle, which results in uneven wear of the claws and could cause lameness. Sogstad et al. (2005a) indicated that the increasing risk of lameness with age might be to the effect of aging and cumulative damages of claw tissue. The quality of cows' claws declines progressively with age, based on the impairment in shape and (or) softening of the horn and internal structures (Rowlands et al., 1985).

Probability of Lameness (Score ≥ 3) and Claw and Leg Diseases (Without Digital Dermatitis) Depending on Lactation Stage Within Lactation Number

Lameness probability differed between lactation stages within and between the 3 parity groups (Figure 4). Our findings regarding the probability of lameness (score ≥ 3) are not directly comparable with the results in the literature because of the separate definition of parity classes as well as the definition of the lactation stage classes within parity. In the literature, lameness was most common during the earliest stage of lactation or within the first month of lactation (Rowlands et al., 1985; Boettcher et al., 1998; Van Dorp et al., 2004). These findings indicate that the environmental, feeding, and metabolic changes before and after calving might result in more lameness cases in the early stage of lactation. High-energy nutrition with a relative low roughage-to-concentrate ratio provokes metabolic diseases, such as ruminal acidosis, which often implicates laminitis and lameness (Boettcher et al., 1998). In contrast, Espejo et al. (2006) could not find any relationship between lameness and lactation stage.

The probability of occurrence of claw and leg diseases is highest in early lactation, which might be a result of the routine claw trimming at that time. Several authors have shown that sole ulcer, which is the most frequent disease in our study, mostly occurs in the first part of lactation. This could be a second reason for the strong peak. Sole ulcer as a feed-related claw disease can be caused by the rapid nutrition change from low energy prepartum to high energy postpartum (Huang et al., 1995; Holzhauer et al., 2006; Buch et al., 2011). The peaks at the end of the lactation might also be caused by the routine claw trimming. The exclusion of digital dermatitis affected the trajectory of the primiparous cows most. The strong peak at the beginning of lactation disappeared and the course remained on a constant low level during lactation. These results emphasize the assumption that first-parity cows are more susceptible to digital dermatitis (Somers et al., 2003, 2005; Holzhauer et al., 2006). The strong peak at the beginning

of lactation in first-parity cows might also originate from purchased heifers as well as in-house heifers that are already affected with the disease.

The exclusion of digital dermatitis also affected the trajectory of claw and leg diseases in cows with at least 3 parities. Omission of the disease resulted in a higher probability for this group of cows because of the altered ratio of diseases in all 3 parity classes. Older cows are more susceptible for claw diseases such as sole ulcer and white line disease but show less frequently signs of digital dermatitis, whereas cows in first parity are more vulnerable to digital dermatitis (Somers et al., 2003, 2005; Holzhauer et al., 2006). Therefore, for first-parity cows, the probability of claw and leg diseases decreases and increases for older cows after omission of digital dermatitis.

Genetic Parameters

Heritability estimates for lameness are in accordance with the results of Boettcher et al. (1998). Using a linear as well as a threshold model, they reported estimates of 0.10 and 0.22, respectively, for clinical lameness. Boelling et al. (2007) estimated a similar value (0.10) using a linear animal model after converting the locomotion scores from the type trait scale (notes 1–9) into 2 categories [lame (class 1) vs. not lame (classes 2–9)]. A former study (Boelling and Pollott, 1998b) found a distinctly lower value of 0.01 for lameness as binary trait [not lame (class 1–4) vs. lame (class 5–9)] after transforming heritability from the binomial scale to the continuous underlying scale. Besides the estimates for lameness as a binary trait, heritabilities for locomotion on the original type classification scale [1 (obvious lameness) to 9 (walks with even gait)] ranged between 0.03 and 0.22 (van der Waaij et al., 2005; Onyiro and Brotherstone, 2008; Laursen et al., 2009; van der Linde et al., 2010; Zink et al., 2011). The trait locomotion as additional conformation trait in the type classification of Holstein-Friesian heifers and lameness as a binary trait examined in our study cannot be compared directly with one another. The 2 traits were recorded with different locomotion scoring systems (1–9 vs. 1–5/0–1) and the objectives were clearly different. Our aim was to examine lameness in primiparous as well as multiparous Holstein-Friesian dairy cows in one herd over a long period of time. The linear trait locomotion is used to describe the stride of Holstein-Friesian cows in first parity at one date and should only be scored if the cow does not show any signs of lameness (ICAR, 2012).

Heritabilities for claw and leg diseases were in agreement with the estimates of different claw diseases from the threshold model reported by Swalve et al. (2008).

van der Waaij et al. (2005) have shown that the heritability estimates using the threshold model and linear model were very similar and ranged from 0.01 (sole ulcer and clinical laminitis) to 0.10 (digital dermatitis and interdigital hyperplasia). Laursen et al. (2009) analyzed claw health data recorded by veterinarians and found a heritability of 0.06 for claw health, which was transformed to the underlying continuous scale with the formula of Dempster and Lerner (1950). The low estimate might stem from the fact that the diseases were scored by veterinarians and not by claw trimmers as in the other studies. Therefore, it could be that only the most severe cases of claw and leg diseases were registered.

Our moderate heritability for lameness estimated with a threshold model as well as the results of Boettcher et al. (1998) indicated that direct selection for reduced lameness could be moderately successful. The results of claw and leg diseases also show that substantial genetic variation does exist.

Genetic correlations between lameness and claw and leg diseases using threshold models were positive and quite large [0.60 vs. 0.72 (without digital dermatitis)], but it should be noted that the estimates were associated with relatively high standard errors. Estimates from linear models were rather higher. According to Gianola (1982) and Vinson et al. (1976), estimates for additive genetic correlations should not be affected by violation of assumption of normality when using linear models for analysis of binary data. However, Stock et al. (2007) showed considerable variation of bias. The genetic correlation between 2 binary traits were overestimated by 13 to 38% as well as biased downward. To the best of our knowledge, genetic correlations between lameness as a binary trait and claw and leg diseases have not been estimated so far. A few authors have estimated genetic correlations between claw and leg lesions and the conformation trait locomotion. For recorded health data by veterinarian, the genetic correlation was 0.46 (Boelling et al., 2008; Laursen et al., 2009). Boelling et al. (2008) found a genetic correlation of 0.79 between claw diseases recorded by claw trimmers and locomotion. All correlations were estimated using linear models.

Based on the genetic correlations, lameness seems to be a good indicator of susceptibility to claw and leg diseases. The increase in the genetic correlation after exclusion of digital dermatitis demonstrates that this disease affects the mobility of the animals less strongly than other claw and leg diseases. With regard to the underlying specific pattern of claw diseases in the trait claw and leg diseases in our study, it should be noted that the relationship might change with a different disease structure. This was already demonstrated by

the omission of digital dermatitis. Due to the limited data set, especially for the lameness cases, the genetic parameters were associated with large standard errors. However, the results indicate that genetic selection for improved health of feet and legs will be feasible. Further research is still needed to confirm the results.

CONCLUSIONS

The estimated genetic parameters presented in this study suggest that lameness might be a useful indicator for claw and leg health. As the parameters are associated with large standard errors, the study should be repeated with a larger data set to confirm the values. Furthermore, the examination of the relationship between the trait lameness, recorded by locomotion score, and the type classification trait locomotion should be analyzed to exclude the possibility that they are the same trait and avoid double recording.

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