Genetic correlations of clinical mastitis and feet and legs problems with milk yield and type traits in Dutch Black and White dairy cattle

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Abstract

Direct selection for decreased disease incidence is difficult given low heritabilities and absence of disease recording. Genetic correlations between diseases and type traits indicate possibilities for indirect selection; however, correlations often include experimentally instead of routinely scored type traits. The aim of this study was to estimate genetic correlations of clinical mastitis and feet and legs problems with milk yield and routinely scored type traits in Dutch Black and White cows. From 1983 to 1991, incidence of diseases was recorded at 44 farms with Dutch Black and White dairy cattle. In total, records on 3617 cows sired by 224 bulls were analyzed. Heritabilities for milk yield, type traits, and diseases were obtained using an equal design multi-variate REML procedure considering all observations on a continuous scale. A bivariate threshold procedure was used to estimate heritabilities for diseases and genetic correlations of diseases with milk yield and type traits. Genetic correlations of clinical mastitis and feet and legs problems with milk yield were unfavorable (0.16, 0.26), and heritabilities for diseases were low (0.01–0.11). Unexpected positive relations between udder type traits and clinical mastitis were found (0.09-0.26), and possible reasons were discussed. Genetic correlations between type traits for feet and legs and feet and legs problems were negative (–0.01, –0.24). Final score for feet and legs might be used as selection criteria to select for lower incidence of feet and legs problems.

Keywords: feet and legs problems, mastitis, milk yield, type traits

Introduction

Incidences of diseases reduces animal welfare and causes economic losses in animal production systems. Major health disorders in dairy cattle include mastitis and feet and legs problems. An important incentive to include selection for mastitis and feet and legs problems in dairy cattle breeding programs is the unfavorable positive genetic correlation with milk yield, indicating that high selection pressure on milk yield might increase disease susceptibility. Genetic correlations between mastitis and milk yield range from 0.0 to 0.5 (e.g., Emanuelson, 1988; Emanuelson *et al.*, 1988; Lyons *et al.*, 1991; Simianer *et al.*, 1991). Lyons *et al.* (1991) estimated a genetic correlation of 0.31 between feet and legs problems and milk yield.

Direct selection for decreased disease incidence is difficult given low heritabilities (<0.10) for mastitis (e.g., Miller, 1984; Solbu, 1984; Emanuelson *et al.*, 1988; Lin *et al.*, 1989; Lyons *et al.*, 1991; Simianer *et al.*, 1991; Koenen *et al.*, 1994) and feet and legs problems (Philipsson *et al.*, 1980; Petersen *et al.*, 1982; Distl *et al.*, 1990) and the absence of disease recording. Genetic correlations between diseases and type traits indicate that indirect selection might control genetic merit for susceptibility for disease (Solbu, 1984; Rogers, 1993). Udder depth, teat placement, and teat length have reasonable genetic correlations with somatic cell count, which is an indicator of (subclinical) mastitis (e.g., Miller, 1984; Seykora & McDaniel, 1986). Politiek *et al.* (1986) and Distl *et al.* (1990) reported that claw diagonal and claw angle have fairly high genetic correlations with incidence of feet and legs problems. Correlations between diseases and type traits often include experimentally measured type traits instead of routinely scored type traits.

The aim of this study was to estimate genetic correlations of clinical mastitis and feet and legs problems with milk yield and routinely scored type traits in Dutch Black and White dairy cattle.

Materials and methods

From 1983 to 1991, incidences of health disorders were recorded at 44 farms in the province of Friesland. Disorders included four main categories: fertility, mastitis, feet and legs problems, and metabolic disorders. All disorders involved clinical incidences, diagnosed by the farmer themselves. Recording was coordinated and controlled by veterinary officers of the Institute for Animal Health "Noord Nederland" in Drachten. There was no selection in farms; farmers voluntarily joined the recording programme. Frequencies of mastitis and feet and legs problems in first lactation (Table 1) were

Table 1. Frequencies of clinical mastitis and feet and legs problems in first lactation cows.

Disease	Frequencies[1] (%)
Clinical mastitis	5.6
Teat injury	0.9
Feet and legs problems	9.3
Periarthritis	0.9
Sole ulcers	1.5
Interdigital dermatitis	2.4
Mortellaro or Digital dermatitis	2.7
Phlegmona interdigitalis	1.9

[1] recorded as the percentage of cows that had a disease at least once during a lactation.

slightly lower than those reported earlier in Dutch herds (Dijkhuizen, 1990).

Data on milk yield and type traits were supplied by the Dutch Cattle Syndicate from routine milk recording and type classification systems. Milk yield data included 305-days first lactation records for kilograms of milk, fat, and protein and percentages of fat and protein. Twice each year, type traits were scored on all freshened cows using a linear scale (six classes, with a high score being beneficial/desired). Type traits included fore udder attachment (weak – strong), front teat placement (wide – narrow), udder depth (deep – shallow), suspensory ligament (weak – strong), rear legs set (straight – bended), and claw diagonal (long – short). Final scores on udder and on feet and legs were also included.

In this study, data were restricted to Dutch Black and White first lactation cows calving after January 1st, 1985 and having records on clinical mastitis, feet and legs problems, milk yield (at least 50 days in milk), and type traits. Other diseases and records on later lactations were not included because of a very low (absolute) number of disease incidents. Only sires having three or more daughters were included in the data. Usually, a higher minimum of daughters per sire might be considered, but a higher minimum would have reduced data considerably (Table 2). Variance components were estimated using the following sire models:

for diseases,

$$I_{ijk} = HYS_i + SIRE_j + b_1\ \%HF + b_2\ HET + b_3\ AGE + b_4\ PERIOD + e_{ijk}$$

for milk yield,

$$P_{ijk} = HYS_i + SIRE_j + b_1{*}\%HF + b_2{*}HET + b_3{*}AGE + e_{ijk}$$

for type traits

$$T_{hjk} = VISIT_h + SIRE_j + b_1{*}\%HF + b_2{*}HET + b_3{*}AGE + b_5 STAGE + e_{hjk}$$

where

$I_{ijk}, P_{ijk}, T_{hjk}$	=	values on disease, milk yield, or type trait on daughter k from sire j in herd-year-season i or visit h;
HYSi	=	the fixed effect of herd-year-season i of calving;
$VISIT_h$	=	the fixed effect of classification visit h to the herd;
$SIRE_j$	=	the random genetic effect of sire j;
%HF	=	the percentage of Holstein-Friesian of the cow;
HET	=	the percentage of heterosis of the cow;
AGE	=	the age at calving;
STAGE	=	the fixed effect of stage of lactation;
PERIOD	=	the fixed effect of the length of the recording period;
$b_1 - b_5$	=	regression coefficients for %HF, HET, AGE, PERIOD, and STAGE, respectively; and
e_{ijk}, e_{hjk}	=	the residual error term.

Table 2. Number of daughters per sire in the data.

Number of daughters per sire	Number of sires	Total number of records by these sires	Cumulative number of records
1 – 2[1]	346	446	
3 – 5	114	402	402
6 – 10	45	328	730
11 – 20	21	291	1021
21 – 50	24	760	1781
51 – 100	13	817	2598
101 – 200	5	613	3211
> 200	2	406	3617
Total	224	3617	

[1] excluded from the analysis

Classes for herd-year-season of calving were January to March, April to June, July to September, and October to December. In the analysis of type traits, the effect of classification visit allowed correction for herd, year, season, and classifier. Proven sires and unproven young bulls were considered to be random effects because the number of daughters of unproven bulls was small. Proven bulls might be considered to be fixed effects to decrease the effect of selection on estimation of (co)variance component and improved data connectedness (Simianer *et al.*, 1991), but the number of daughters of unproven bulls was too small. A matrix of additive genetic relationships between sires (two pedigree generations) was included in the mixed model equations. Percentages of Holstein-Friesian and heterosis were considered in the model because the data contained Dutch Black and White cows that originated from matings Dutch Friesian and Holstein-Friesian ancestors (Van der Werf, 1990).

Length of the recording period was considered in the analysis of diseases to allow for different probabilities of cows being diseased by having a longer observations period.

The effect of stage of lactation in the analysis of type traits considered four classes: 0 to 65, 66 to 125, 126 to 185, and >185 days after calving.

Heritabilities for milk yield, type traits and diseases were obtained using an equal design, multivariate REML procedure (Meyer, 1991), in which observations on all traits were considered on a continuous scale. However, diseases were recorded in a binary form (0 = nondiseased and 1 = ≥1 incidents). A bivariate threshold procedure, considering one trait on a continuous scale and the other trait on a two-point scale (Janss & Foulley, 1993), was used to obtain solutions for heritabilities for diseases and genetic correlations of diseases with milk yield and type traits.

Table 3. Heritabilities (standard error) for milk yield in 305-days first lactation records and for type traits in cows estimated with a model assuming a continuous scale.

Trait		Heritability
Milk yield	kg Milk	0.24 (0.06)
	kg Fat	0.22 (0.06)
	kg Protein	0.20 (0.06)
	% Fat	0.41 (0.08)
	% Protein	0.52 (0.09)
Type traits	Fore udder attachment	0.27 (0.06)
	Front teat placement	0.39 (0.08)
	Udder depth	0.41 (0.08)
	Suspensory ligament	0.17 (0.05)
	Udder (final score)	0.31 (0.06)
	Rear legs set	0.21 (0.06)
	Claw diagonal[1]	0.18 (0.05)
	Feet and legs (final score)	0.21 (0.06)

[1] only data on 1700 cows were available

Results and discussion

Heritabilities for milk yield and type traits with a linear model are in Table 3. Heritabilities for milk yield were lower than reported by Van der Werf (1990). Heritabilities for type traits were consistent with results of Ouweltjes (1991) obtained from nationwide Dutch data. Most cows with records in the data were daughters of proven bulls, that were highly selected for milk yield. This fact might have

Table 4. Variance components and heritabilities (standard errors) for disease traits in cows.

Disease	Model assuming a continuous scale			Threshold model[1]
	Genetic variance $* 10^{-3}$	Phenotypic variance $* 10^{-2}$	Heritability	Heritability
Clinical mastitis	1.26	5.24	0.02 (0.01)	0.06
Teat injury	1.21	5.15	0.02 (0.01)	
Feet and legs problems	1.38	7.39	0.02 (0.01)	0.04
Periarthritis	0.06	0.90	0.01 (0.00)	
Sole ulcers	0.27	1.31	0.02 (0.01)	
Dermatitis Interdigitalis	0.16	2.18	0.01 (0.00)	
Mortellaro	0.40	2.29	0.02 (0.01)	
Phlegmona Interdigitalis	1.88	1.73	0.11 (0.04)	

[1] the threshold model gave no standard errors

Table 5. Genetic correlations for mastitis and feet and legs problems with milk yield and type traits (estimated with a treshold model, no standard errors available) in cows.

Trait	Mastitis	Feet and legs problems
Milk yield	0.16	0.26
Fore udder attachment	0.09	
Front teat placement	0.11	
Udder depth	0.18	
Suspensory ligament	0.26	
Udder (final score)	0.18	
Rear legs set		–0.01
Feet and legs (final score)		–0.24

caused the lower heritabilities (relative to those by Van der Werf (1990)) for milk yield but apparently did not influence heritabilities for type traits.

Heritabilities for diseases in cows (Table 4) are low (0.01 to 0.11), as expected. Heritabilities for diseases are higher using the threshold model than the continuous model because the threshold model corrects for low frequencies of the disease (Gianola, 1980). Correction of the heritabilities assuming a continuous scale for low frequencies according to Philipson *et al.* (1980) gave estimates that were slightly higher than observed with the treshold model (0.08 for clinical mastitis and 0.05 for feet and legs problems).

Genetic correlations of diseases with milk yield (Table 5) were positive, unfavorable, and low. The analysis considered 305-days lactation records, either predicted from part lactation records (at least 50 days in milk) or actual 305-days lactations. Although the potential for higher milk yield might be associated with higher probability of disease, occurrence of disease would have reduced actual milk yield (Houben *et al.*, 1993). Confounding of these effects might bias estimates for the correlation between milk yield and disease. Genetic correlation for final feet and legs score with feet and legs problems was moderately negative (–0.24, Table 5): the higher the final score, the lower disease incidence. Because of low numbers of observations, genetic correlation for claw diagonal with disease incidence was not estimated.

Surprisingly, udder conformation was positively related to clinical mastitis: better udder conformation should indicate a higher incidence of clinical mastitis? Three possible reasons for this result should be mentioned.

In estimation of the correlations between clinical mastitis and udder traits, the threshold model could not converge and was stopped after 30 rounds of iteration. Convergence was reached for correlations between feet and legs diseases with type traits.

The dominant role of proven bulls might have had an impact on correlations between disease traits and milk yield and type traits, as suggested, for example, by the unfavorable correlation between mastitis and final udder score. Mastitis is a complex disease in which udder conformation may be involved. Although, better udder conformation generally can be associated with less mastitis (e.g., Miller, 1984; Seykora & McDaniel, 1986), for an individual bull this is not necessarily true. To illustrate this point, the bull Tops Monitor Legend was found to have a high transmitting ability for both udder type and clinical mastitis resistance (206 daughters in the analysis, absolute incidence of clinical mastitis among daughters 4%), but the bull Nehls Chief Crusader combined a high transmitting ability for udder type with a low transmitting ability for clinical mastitis resistance (73 daughters, 11% incidence). Original data included a large number of daughters of young unproven bulls, but most bulls had only 1 or 2 daughters. When such a large-scale experiment is repeated, testing of young bulls should be coordinated to obtain a better data structure for more accurate estimation of correlations.

In this analysis, linear relationships between clinical diseases and type traits were assumed. Relationships, especially for udder traits under the Dutch type classification system, might be nonlinear (Luykx *et al.*, 1992). Rogers & Hargrove (1993) found that quadratic relationships between genetic evaluations for udder traits and somatic cell scores were not important; only a quadratic component for teat length and somatic cell count was significant. Nonlinearity of relationships between clinical diseases and type traits need to be studied in more detail to optimize strategies for selection and mating.

In the Netherlands, incidence of diseases is not routinely recorded, and this practice is not likely to be implemented in the near future. Selection on reduced incidence of diseases might be based on indirect selection, using an index from routinely scored traits, despite a low accuracy. A mastitis index could be based on somatic cell count, front teat placement, and udder depth (Rogers, 1993). In this study, relationships between udder conformation and clinical mastitis incidence were not confirmed. Final score for feet and legs as recorded in the Dutch type classification systems might be a criterion for selection on reduced feet and legs problems.

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