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ABSTRACT

Information from 7712 lactations of Holstein dairy cows was collected from 33 commercial herds around Ithaca, NY in the 3 yr from 1981 to 1983. The data were divided into subsets corresponding to lactation 1, lactation 2, and lactation 3 or greater. To estimate heritabilities of dystocia, retained placenta, metritis, ovarian cysts, milk fever, and mastitis, a mixed linear model (herd-year fixed and sire random effects) with 0 or 1 as the observed response was used. Variance components were estimated using Henderson's Method 3. The results show moderate heritabilities (.15 to .40) for dystocia, metritis, milk fever, and mastitis and low heritability (less than .12) for retained placenta and cystic ovaries. Genetic correlations between dystocia, retained placenta, metritis, and mastitis were moderate in size and positive, whereas cystic ovaries were correlated negatively with dystocia and retained placenta. A general reproductive health trait (dystocia, retained placenta, metritis, cystic ovaries, and milk fever combined in one trait) also was analyzed. The estimated heritability of this trait was .21, .11, and .00 for first calf heifers, second lactation cows, and older cows, respectively.

INTRODUCTION

Health disorders in Holstein cows considered in this study were dystocia, retained placenta, metritis, cystic ovaries, milk fever, and mastitis. The incidence rates for these diseases (1, 3, 9, 13, 15) and the relationships among them (5, 7) have been studied extensively. The associated economic losses due to increased days to first breeding and days open, lower conception rate, lower milk yield, and higher probability of culling have been investigated (2, 7, 8, 14, 17). Smith et al. (19) estimated average losses per year due to impaired reproductive performance and increased culling caused by reproductive disorders to be $9.90 for first calf herifes and $23.60 for mature cows.

The involvement of genetic factors in the incidence of these disorders is suspected because the incidence rates are higher among relatives of affected individuals than in the general population (3, 4, 6, 11, 12). The presence of an underlying genetic component suggests the potential for improvement in disease resistance through selection.

In dairy cattle, a heritability of dystocia of .17 for first calf heifers, .08 for second parity cows, and .05 for third and greater parity cows was reported by Pollak and Freeman (15), and an overall heritability of .01 was estimated by Martinez et al. (12). For retained placenta, a heritability estimate of .38 was reported by Erb et al. (8). For milk fever, Dyrendhal et al. (6) estimated heritability to be .13 in the Swedish Red Breed and .07 in Swedish Friesians. A California study conducted by Thompson (22) also estimated heritabilities for paturition problems and various other problems in Holstein cows. For dystocia,

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estimated heritability was .06; .13 for milk fever, .05 for retained placenta, and .03 for mastitis. Using pedigree analysis, a significant hereditary risk factor for cystic ovaries in Holstein cows was reported by Cole et al. (4), giving support to similar results reported earlier by Krit et al. (11).

The objective of this study was to estimate additive genetic variance and heritability associated with the incidences of six health problems, using data collected in a group of herds representative of the Northeast US dairy population.

MATERIALS AND METHODS

All 33 commercial dairy herds in the study met the following criteria: the herd 1) had more than 35 milking cows, which were primarily bred using AI, 2) was enrolled in the New York Dairy Herd Improvement program, 3) used the herd health program provided by the New York State College of Veterinary Medicine, and 4) was in the vicinity of Ithaca, NY. All health data were recorded monthly or semimonthly by a research technician. Emphasis was placed on accurate recording of calving, health, breeding, culling, and management practices. Data were collected for all cows freshening between March 1981 and August 1983. Each lactation could be terminated at any stage by death, sale, or drying off. The data set is the result of a carefully designed and conducted field study and is probably the best available recording of clinical diseases in commercial US dairy herds. A complete description of data collection and editing is in work by Erb et al. (7).

Each of the six health problems was coded as either 0 (absence) or 1 (presence). The definition of metritis in this study included clinically diagnosed cases of metritis, endometritis, and pyometra. The definition of cystic ovaries included cystic follicles and luteal cysts, and the diagnosis was based upon rectal palpation of ovarian structures by the veterinary practitioner. Milk fever and mastitis (which included coliform mastitis) were diagnosed either by the farmer or by the veterinary practitioner. The occurrence of dystocia was determined by asking farmers after each parturition whether the cows received any assistance (either by farmer or by veterinarian) during delivery. A cow was considered to have retained placenta if all fetal membranes were not expelled within 24 h after parturition; recording also was based on farmers' responses.

Health information for a total of 7712 lactations was collected during the 3 yr period of the field study. From these records, one cow without herd identification, five cows with duplicate lactation numbers, and 1510 lactation records with unknown sire code were deleted. The remaining data set was divided into three subsets according to the cow's lactation number: first calf heifer group, second lactation group, and third or greater lactation group (from lactation 3 to lactation 13). For the last group, only the first record of third or greater lactation each cow had during the study period was included in the data for analysis.

Records coded as free of certain disease deserve special attention. Except for dystocia and retained placenta, which occur at parturition, incidence of the other four health problems included in this study can extend from parturition to the end of the milking period. Only those cows' records that were free of metritis, cystic ovaries, milk fever, and mastitis longer than the postpartum period required for the incidence of the 75% of the cases for each of these diseases to occur were considered in the analysis (Table 1).

The following model was used to describe the observations:

$$y_{ijk} = hs_i + s_j + e_{ijk}$$

where:

y_{ijk} is an idividual observation for a cow calving in the i^{th} herd-season and with the j^{th} sire and describes health status for a specific disorder on the observed scale;

hs_i is a fixed effect associated with i^{th} herd-season (with two seasons, November through April, and May through October);

s_j is a random effect associated with the j^{th} sire (assumed to be normally and independently distributed with mean zero and variance $\sigma^2{}_s$); and

e_{ijk} is a random residual component associated with ijk^{th} observation (assumed to be normally and independently distributed with mean zero and variance $\sigma^2{}_e$).

TABLE 1. Incidence rates and 75th percentile (pct) for days postpartum at diagnosis for six health problems by lactation groups.

Lactation group	Observations	Cases	Incidence	Days at diagnosis (75th pct)
	(n)		(%)	
First calf heifers				
Dystocia	1722	292	16.9	0
Retained placenta	1722	76	4.4	0
Metritis	1704	151	8.8	31
Cystic ovaries	1591	68	4.2	124
Milk fever	1702	15	.8	0
Mastitis	1591	156	9.8	144
Second lactation cows				
Dystocia	1498	100	6.6	0
Retained placenta	1498	125	8.3	0
Metritis	1479	118	7.9	35
Cystic ovaries	1369	128	9.3	142
Milk fever	1494	43	2.8	0
Mastitis	1387	180	12.9	137
Older cows				
Dystocia	1688	140	8.2	0
Retained placenta	1688	216	12.7	0
Metritis	1637	217	13.2	39
Cystic ovaries	1567	183	11.6	118
Milk fever	1675	147	8.7	0
Mastitis	1560	229	14.6	148

Least squares equations for herd-season effects were removed by absorption and the sire and residual components of variance were estimated using the Varcomp procedure from SAS statistical procedures (18). The Type I method in the Varcomp procedure estimates the variance components by equating the mean squares for random effects to their expected values and is, therefore, equivalent to Henderson's Method 3 of estimation (10).

Heritability was estimated using the formula:

$$h^2 = 4\sigma^2_s/(\sigma^2_s + \sigma^2_e)$$

Standard error of the estimate was approximated using the method described by Swinger et al. (20). Genetic correlations among various pairs of disorcers for each lactation group were estimated as:

$$r_{g1g2} = \sigma_{s1s2}/(\sigma^2_{s1} \times \sigma^2_{s2})^{.5}$$

where σ_{s1s2} is sire covariance for disease 1 and 2 and is estimated from the analysis of measurements of the two diseases on the same animal (observed scale), and the denominator is the product of the sire variances for the two diseases.

RESULTS AND DISCUSSION

The incidence rates were increasing with parity for all problems but dystocia for which it decreased (Table 1). The incidence rate for milk fever in first calf heifers was very low; therefore, this disease was not considered further for first calf heifers.

Except for dystocia, retained placenta, and metritis in the oldest lactation group, all estimates of the sire component of variance were positive (Table 2). In general, the resulting heritability estimates (Table 3) were relatively high compared with other reports. Large variability among heritability estimates for health problems is to be expected because of differences in the clinical definition of diseases, in the accuracy of data recording, and in sample sizes.

Current estimate of .14 for heritability of dystocia in first calf heifers and .15 for second

TABLE 2. The estimates of the sire and residual component of variance for the six health problems.

Lactation group	Dystocia	Retained placenta	Metritis	Cystic ovaries	Milk fever	Mastitis
First calf heifers (54 to 60 herd-seasons, 319–336 sires)						
σ^2_s [1]	.005	.000	.004	.001	...	.004
σ^2_e [2]	.125	.041	.073	.040	...	.081
Second lactation cows (55 to 61 herd-seasons, 299 to 315 sires)						
σ^2_s [1]	.002	.002	.005	.002	.002	.008
σ^2_e [2]	.059	.073	.066	.083	.025	.097
Older cows (56 to 60 herd-seasons, 382 to 399 sires)						
σ^2_s [1]	−.000	−.002	−.003	.000	.008	.005
σ^2_e [2]	.075	.111	.113	.101	.068	.111

[1] Sire component of variance.

[2] Residual component of variance.

lactation cows is in agreement with estimates of .13 and .17 reported by Brinks et al. (2) and Pollak and Freeman (15), respectively. Thompson's (22) estimates for heritability were lower for milk fever and mastitis than in this study, but the estimates for retained placenta are comparable.

Several genetic correlations were not calculated because of negative estimates of the sire component of variance. Among those calculated (Table 4), the correlations of metritis with cystic ovaries in first calf heifers, of milk fever with dystocia, retained placenta, and mastitis in second lactation cows, and correlation of mastitis with cystic ovaries and with milk fever in older cows were low (<.1). The estimates for most other pairs of problems indicated a moderate genetic correlation, except dystocia with metritis and with mastitis in first calf heifers and retained placenta with

TABLE 3. Heritabilities (h^2) of six health problems and their approximate standard errors for each lactation group.

Lactation group	Dystocia	Retained placenta	Metritis	Cystic ovaries	Milk fever	Mastitis
First-calf heifers						
h^2	.144	.050	.191	.119	...	.186
SE	.077	.070	.077	.077	...	.077
Second lactation cows						
h^2	.154	.091	.262	.076	.296	.310
SE	.084	.077	.089	.084	.089	.100
Older cows						
h^2	NE[1]	NE	NE	.016	.420	.179
SE	NE	NE	NE	.084	.095	.089

[1] Not estimable because of negative estimate of sire variance.

TABLE 4. Genetic correlations among six health problems from each lactation group.

Lactation group	Dystocia	Retained placenta	Metritis	Cystic ovaries	Milk fever
First calf heifers					
Retained placenta	.32	...	...	...	...
Metritis	.95	.24	...	...	...
Cystic ovaries	NE[1]	NE	−.01	...	...
Mastitis	.80	.40	.38	.26	...
Second lactation cows					
Retained placenta	.41	...	...	...	...
Metritis	.28	1.19	...	...	...
Cystic ovaries	−.47	−.64	.49	...	...
Milk fever	−.02	−.00	−.15	.20	...
Mastitis	NE	NE	.59	.11	−.06
Older cows					
Retained placents	NE	...	...	...	...
Metritis	NE	NE	...	...	...
Cystic ovaries	NE	NE	NE	...	...
Milk fever	NE	NE	NE	.40	...
Mastitis	NE	NE	NE	.03	−.03

[1] Not estimable because of negative estimate of sire component of variance.

metritis in second lactation cows for which the estimates were high (>.8). Most genetic correlations that were moderate to high in magnitude were positive, indicating a direct genetic association between diseases. Only correlations between dystocia and cystic ovaries, retained placenta and cystic ovaries, and milk fever and metritis in second lactation cows were negative (indicating an inverse genetic association).

Analysis of a combined health trait (for convenience labeled "general reproductive health") was also performed. Milk fever was included because it occurs usually around parturition and greatly increased the risks of retained placenta and metritis (7). The trait was defined as 0, 1, or 2 (representing the occurrence of 0, 1, and 2 or more of the six health problems during a lactation record). The rationale behind this approach was that the total number of disorders might be a better indicator of general disease resistance than a single disorder. The expected decline in general reproductive health with age was present (Table 5). The estimation of the variance components was performed as described, but with the dependent variable now taking the value of 0, 1, or 2. An added advantage of this approach is that, with more response classes and less likelihood of rare events, more robust estimates can be obtained.

Heritability of general reproductive health was .21 and .11 for first calf heifers and second lactation cows, respectively (Table 6). For older

TABLE 5. Incidence rate of 0, 1, and 2 or more health problems[1] by lactation group.

Lactation group	Number of records	Incidence (%)		
		0	1	2+
First calf heifers	1591	72.3	21.7	6.0
Second lactation cows	1369	73.5	20.0	6.5
Older cows	1567	61.8	26.5	11.7

[1] Dystocia, retained placenta, metritis, milk fever, and cystic ovaries.

TABLE 6. Estimates of sire and residual components of variance and of heritability with associated standard error for general reproductive health trait[1] for each lactation group.

Estimate	Lactation group 1	2	≥3
Sire variance	.017	.009	−.003
Residual variance	.309	.322	.462
Heritability (h^2)	.207	.105	NE[2]
Standard error h^2	.007	.007	...

[1]General reproductive health is defined as 0, 1, or 2, indicating the presence of 0, 1, and 2 or more of the problems included in the trait (dystocia, retained placenta, metritis, cystic ovaries, and milk fever).

[2]Not estimable because of negative estimate of sire variance.

cows, heritability was not estimable because of negative estimate of sire variance and was inferred to be very close to 0. The trend of higher heritability in first calf heifers and lower heritability in older cows for health related traits, also shown by Saloniemi et al. (16) for dystocia, retained placenta, and metritis and by Syvajarvy et al. (21) for clinical mastitis, is probably the result of selection and culling. The information provided by first calf heifers might therefore be sufficient for improving disease resistance through selection.

CONCLUSIONS

All six health problems considered in this study usually are defined broadly. This situation leaves room for subjective interpretation and, therefore, makes heritability estimates of these diseases from different studies difficult to compare. To evaluate objectively the potential for improving health status in dairy cattle through selection, accurate measures of these genetic parameters are required. The decline in heritability with age for many diseases needs to be further investigated. If confirmed, it may indicate that although incidence rate for many diseases increases with age, genetic evaluation of animals by first lactation records only might be sufficient for selection.

In this study, heritability estimates for dystocia, metritis, mastitis, and milk fever were .15 or greater, suggesting that selection can improve the health status of the dairy cows with respect to these problems. Genetic correlations between dystocia, retained placenta, metritis, and mastitis were positive and moderate in size, indicating that selection for any one of these health problems would result in a positive correlated effect with respect to the other diseases. Heritability of "general reproductive health" trait was .21, .11, and .00 for first calf heifers, second lactation cows, and older cows, respectively.

REFERENCES

1 Arthur, G. H. 1979. Retention of the afterbirth in cattle: a review and commentary. Vet. Ann. 19:26.

2 Brinks, J. S., J. E. Olson, and E. J. Carroll. 1973. Calving difficulty and its association with subsequent productivity in Herefords. J. Anim. Sci. 36:11.

3 Casida, L. E., and A. B. Chapman. 1951. Factors affecting the incidence of cystic ovaries in a herd of Holstein cows. J. Dairy Sci. 34:1200.

4 Cole, W. J., C. J. Bierschwal, R. S. Youngquist, and W. F. Braun. 1986. Cystic ovarian disease in a herd of Holstein cows: a hereditary correlation. Theriogenology 25:813.

5 Curtis, C. R., H. N. Erb, C. J. Sniffen, R. D. Smith, and D. S. Kronfeld. 1985. Path analysis of dry period, nutrition, postpartum metabolic and reproductive disorders, and mastitis in Holstein cows. J. Dairy Sci. 68:2347.

6 Dyrendahl, I., B. Henricson, and G. Jonsson. 1972. Clinical puerperal paresis and hypocalcemia in cattle: A statistical genetic investigation. Zentralbl. Veterinaermed. A 19:621.

7 Erb, H. N., R. D. Smith, and P. A. Oltenacu. 1985. Path model of reproductive disorders and performance , milk fever, mastitis, milk yield, and culling in Holstein cows. J. Dairy Sci. 68:3337.

8 Erb, R. E., P. M. Hinze, E. M. Gildow, and R. A. Morrison. 1958. Retained fetal membranes: the effect on prolificacy of dairy cattle. J. Am. Vet. Med. Assoc. 133:489.

9 Francos, G. 1979. The relationship between the incidence of endometritis and repeat breeders in dairy herds. Refu. Vet. 36:1331.

10 Henderson, C. R. 1953. Estimation of variance and covariance components. Biometrics 9:226.

11 Krit, J. H., E. M. Huffman, and M. Lane. 1982. Bovine cystic ovarian disease: hereditary relationship and case study. J. Am. Vet. Med. Assoc. 181: 474.

12 Martinez, M. L., A. E. Freeman, and P. J. Berger. 1983. Genetic relationship between calf livability and calving difficulty of Holsteins. J. Dairy Sci. 66:1494.

13 Philipsson, J. 1976. Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. Acta Agric. Scand. 26:230.

14 Philpot, W. N., and F. H. Dodd. 1978. Strategy of mastitis control. Large dairy herd management.

Wilcox and H. H. Van Horn, ed. Univ. Press of Florida, Gainesville.
15 Pollak, E. J., and A. E. Freeman. 1976. Parameter estimation and sire evaluation for dystocia and calf size in Holsteins. J. Dairy Sci. 59:1817.
16 Saloniemi, H., Y. Grohn, and J. Syvajarvi. 1986. An epidemiological and genetic study on registered diseases in Finnish Ayrshire cattle. II. Reproductive disorders. Acta Vet. Scand. 27:196–208.
17 Sandals, W.C.D., R. A. Curtis, J. F. Cote, and S. W. Martin. 1979. The effects of retained placenta and metritis complex on reproductive performance in dairy cattle. A case control study. Can. Vet. J. 20:131.
18 SAS User's Guide: Statistics. 1982. SAS Inst., Inc., Cary, NC.
19 Smith, R. D., P. A. Oltenacu, and H. N. Erb. 1985. The economics of improved reproductive performance. Dairy integrated reproductive management. Cornell Univ., Anim. Sci. Mimeo. Ser. No. 88, IRM-17, Ithaca, NY.
20 Swiger, L. A., W. R. Harvey, D. O. Everson, and K. E. Gregory. 1964. The variance of intra-class correlations involving groupings with one observation. Biometrics 20:818.
21 Syvajarvi, J., H. Saloniemi, and Y. Grohn. 1986. An epidemiological and genetic study on registered diseases in Finnish Ayrshire cattle. IV. Clinical mastitis. Acta. Vet. Scand. 27:223–234.
22 Thompson, J. R. 1984. Genetic interrelationships of parturition problems and production. J. Dairy Sci. 67:628.