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Prediction of Heifer Transmitting Ability from Genetic Evaluations of Sire, Dam, and Maternal Grandsire

R. A. Westell
Cornell University

L. Dale Van Vleck
University of Nebraska-Lincoln, dvan-vleck1@unl.edu

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R. A. WESTELL and L. D. VAN VLECK
Department of Animal Science
Cornell University
Ithaca, NY 14853

ABSTRACT

Estimated transmitting abilities for milk of 258,201 Holstein heifers from first lactations were regressed on sire's milk proof, maternal grandsire's milk proof, and either dam's estimated transmitting ability from milk in first lactation or dams's estimated transmitting ability from milk of all lactations. Effects of year of birth of dam, dam's estimated transmitting ability for milk from first lactation, for milk from all lactations, estimated transmitting ability for fat from first lactation or for fat from all lactations were determined by sorting data into deciles by each of these criteria and calculating partial regression coefficients within each decile. For data in deciles on dams's estimated transmitting ability for milk in first lactation, no further information was gained from all lactations. Partial regression coefficients from regression of heifer's estimated transmitting ability from first lactation on dam's estimated transmitting ability from first lactation, maternal grandsire's proof, and sire's proof were similar to approximate theoretical upper limits. The partial regression coefficient for dam's estimated transmitting ability from all lactations was much smaller than expected. Because regression on dam's estimated transmitting ability from first lactation resulted in weights more closely approximating theoretical upper limits than weights from regression on dam's estimated transmitting ability from all lactations, the use of the former is preferred to predict heifer's estimated transmitting ability from first lactation.

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INTRODUCTION

Pedigree indexing of progeny permits informed decisions concerning purchase, culling, and breeding of dairy stock. Accuracy of pedigree indexing is essential to successful utilization. Decision makers are confronted with a variety of measures of genetic merit for sires and dams. Because females may complete multiple lactations, one must decide which lactation or combination of lactations should be included in pedigree indexing.

Several studies have assessed the relative importance of evaluations of dam's genetic merit by first lactation versus multiple lactations in pedigree indexing of young bulls (2, 4, 5, 7). Partial regression coefficients for evaluations of dams on multiple lactations differ from theoretical approximations. Possible explanations have included preferential treatment for dams of bulls (2, 5). Pedigree evaluation of heifers is also of concern to breeding organizations for identification of potential dams of artificial insemination (AI) bulls and to the dairy producer for determining breeding or culling strategies. The purpose of this study was 1) to determine whether partial regression coefficients for prediction of heifer's estimated transmitting ability (ETA) calculated from only first lactation records from sire's Northeast AI Sire Comparison (NEAISC), maternal grandsire's (MGS) NEAISC, and either dam's ETA calculated from only first lactations or dam's ETA calculated from all lactations agreed with approximate theoretical coefficients; and 2) to determine the effect that dam's ETA or date of dam's birth had on partial regression coefficients.

MATERIALS AND METHODS

Estimation of Partial Regression Coefficients

Records were obtained from files of the New York Dairy Records Processing Laboratory (DRPL) for 258,201 Holstein heifers. Each

record was required to have ETA for milk and fat for first and all lactation records, dam's ETA from first lactation records, sire's NEAISC, and MGS's NEAISC. First lactation ETA were computed from only the first lactations of the heifer and her herdmates. Dam's all lactation ETA were calculated from all records of the dam and her herdmates. The most recent ETA was recorded as the dam's all lactation ETA. Partial regression coefficients to predict heifer's ETA for milk from first lactation were calculated from sire's milk NEAISC, MGS's milk NEAISC, and either dam's ETA for milk from first lactation or from all lactations. Heifer ETA for fat from first lactation also was regressed on estimates of relatives' genetic merit for fat. Partial regression coefficients were compared to approximate theoretical regression weights. Records also were partitioned into deciles according to:

1) dam's ETA for milk from first lactation (highest rated dams in first decile);

2) dam's ETA for milk from all lactations (highest rated dams in first decile);

3) dam's birth date (dams born recently in first decile);

4) dam's ETA for fat from first lactation (highest rated dams in first decile); and

5) dam's ETA for fat from all lactations (highest rated dams in first decile)

to determine effects on the partial regression coefficients. The regression model was:

$$\hat{g}_{ijkl} = \mu + b_1\hat{g}_i + b_2\hat{g}_j + b_3\hat{g}_{jk}$$

where:

μ = mean effect;
$\hat{g}_i$ = NEAISC of the i^{th} sire,
$\hat{g}_j$ = NEAISC of the j^{th} MGS,
$\hat{g}_{jk}$ = ETA of the jk^{th} dam,
$\hat{g}_{ijkl}$ = ETA for first lactation of the l^{th} daughter of the i^{th} sire and jk^{th} dam; and
b_1, b_2, b_3 = partial regression coefficients.

Each regression equation was solved within each type of sorting procedure and within each decile partition such that partial regression coefficients were calculated from either a) dam's ETA from first lactation, or b) dam's ETA from all lactations. Standard errors of regression coefficients were calculated along with multiple correlation coefficients for each regression equation.

Approximation of Theoretical Partial Regression Coefficients

Approximate theoretical partial regression weights can be derived for prediction of a daughter's genetic evaluation from the genetic evaluation of her sire, dam, and maternal grandsire without prior knowledge of these evaluations. Derivation is based upon determining expected values of genetic relationships. Heritability for first lactation was .25; heritability of second and later lactations was .2; genetic correlation between first lactation and subsequent lactations was .8; and repeatability was .5.

Weights were derived by solving:

$$\hat{b} = V^{-1}C$$

where:

$\hat{b}$ = the vector of approximate theoretical regression weights;
V = the variance-covariance matrix of estimated breeding values of dam, sire, and MGS; and
C = the vector of covariances of heifer's estimated breeding value with dam, sire, and MGS estimated breeding values.

Variances and covariances were computed from expected values taken with consideration that the heifer's first lactation contributed to the sire's NEAISC and that the dam's first lactation contributed to the MGS's NEAISC, etc. Expected values were derived in the same manner as (6) with varying numbers of dam's records, sire's progeny, and MGS's progeny.

RESULTS AND DISCUSSION

Theoretical Weights

Table 1 presents approximate theoretical regression coefficients for regression of heifer's ETA from first lactation on dam's ETA, sire's NEAISC, and MGS's NEAISC. Increasing the number of dam's records contributing to estimation of dam's ETA tends to decrease dam's weight and decrease MGS's weight but has little effect on sire's weight. Increasing the number of progeny contributing to estimation of the

TABLE 1. Approximate theoretical regression coefficients for regression of heifer's estimated transmitting ability (ETA) from first lactation records on dam's ETA, sire's Northeast Artificial Insemination Sire Comparison (NEAISC), and maternal grandsire (MGS) NEAISC.

No. MGS progeny	No. dam records	Sire progeny 20 Dam	MGS	Sire	100 Dam	MGS	Sire	1000 Dam	MGS	Sire	5000 Dam	MGS	Sire
20	1	.82	−.23	.56	.80	−.22	.51	.79	−.21	.50	.79	−.21	.50
	3	.67	−.14	.56	.67	−.13	.51	.66	−.13	.50	.66	−.13	.50
	5	.64	−.12	.57	.64	−.11	.51	.63	−.11	.50	.63	−.11	.50
	10	.62	−.11	.57	.61	−.10	.51	.61	−.10	.50	.61	−.10	.50
100	1	.87	−.24	.56	.85	−.23	.51	.84	−.22	.50	.84	−.22	.50
	3	.71	−.15	.56	.70	−.14	.51	.69	−.13	.50	.69	−.13	.50
	5	.67	−.13	.56	.66	−.12	.51	.66	−.12	.50	.66	−.12	.50
	10	.65	−.11	.57	.64	−.10	.51	.63	−.10	.50	.63	−.10	.50
1000	1	.90	−.25	.56	.87	−.23	.51	.86	−.23	.50	.86	−.23	.50
	3	.73	−.15	.56	.71	−.14	.51	.71	−.14	.50	.70	−.14	.50
	5	.69	−.13	.56	.68	−.12	.51	.67	−.12	.50	.67	−.12	.50
	10	.66	−.12	.56	.65	−.11	.51	.64	−.10	.50	.64	−.10	.50

MGS's NEAISC increases both dam's weight and MGS's weight slightly but has little effect upon sire's partial regression coefficient. Increasing the number of progeny contributing to the sire's NEAISC proof slightly decreases dam's, sire's, and MGS's weights.

Empirical and Theoretical Comparisons

Estimated partial regression coefficients for prediction of heifer's ETA from milk in first lactation from sire's milk NEAISC. MGS's milk NEAISC, and either dam's ETA from milk in first lactation, or dam's ETA from milk of all lactations are in Tables 2 to 3 along with squared multiple correlation coefficients, R^2, and maximum standard errors of weights within deciles.

Certain patterns were consistent throughout the analysis. Partial regression coefficients associated with sire's proof ranged between .434 and .498. These were similar to approximate theoretical weights of .50 to .51 and are consistent with weights to predict proofs of bulls from pedigree information (2,5,8). Sire weight was not affected by use of dam's ETA from first lactation as compared to the dam's ETA from all lactations or by observations categorized into deciles by any of the stratifying measures. Weight for the dam's ETA from first lactation was always greater than the weight for dam's ETA from all lactations. Powell et al. (3) reported regression weights to predict heifer's Modified Contemporary Deviation (MCD) for first lactation for milk from dam's MCD for milk in first lactation and from dam's MCD for milk of third lactation were .141 and .028. Murphy et al. (2) found partial regression weights for prediction of son's genetic evaluations for milk were larger when dam's ETA from first lactation was used than when dam's ETA from milk in all lactations was used. Weights for the dam's ETA from first lactation also approached approximate theoretical limits closely, but weights for ETA from all lactations were smaller than theoretical approximations. Regardless of sorting, regression coefficients for dam's ETA from first lactation were close to theoretical expectations. Regression coefficients for dam's ETA from all lactations were smaller than theoretical approximations.

The weight for maternal grandsire's proof was always small. When the regression equation

TABLE 2. Partial regression coefficients for heifer's estimated transmitting ability (ETA) from first lactation records on dam's ETA from first or all lactation records, sire's milk Northeast Artificial Insemination Sire Comparison (NEAISC), and maternal grandsire's (MGS) milk NEAISC within deciles sorted by dam's ETA from first lactation milk records.

	Regression coefficients including dam's ETA from first lactations				Regression coefficients including dam's ETA from all lactations			
Decile[1]	Dam	Sire	MGS	R^2 [2]	Dam	Sire	MGS	R^2 [2]
1	.784	.474	−.162	.69	.222	.468	−.147	.57
2	.767	.484	−.153	.70	.000	.483	−.147	.68
3	.825	.481	−.138	.72	−.001	.481	−.133	.71
4	.936	.481	−.143	.73	.003	.482	−.140	.72
5	.911	.473	−.142	.71	−.005	.473	−.139	.70
6	.721	.487	−.134	.73	.003	.487	−.130	.73
7	.760	.484	−.131	.74	.008	.484	−.125	.73
8	.710	.486	−.125	.74	.014	.485	−.116	.73
9	.699	.491	−.119	.75	.021	.493	−.105	.73
10	.673	.493	−.104	.77	.187	.487	−.018	.73
All	.755	.484	−.135	.84	.391	.472	.048	.70
SE[3]	.0450	.0022	.0035		.0045	.0065	.0032	

[1] Heifer records with highest ranking dams for ETA from first lactation milk records are in decile 1.

[2] R^2 = Squared multiple correlation coefficient.

[3] SE = Largest standard error of the partial regression coefficients across deciles.

TABLE 3. Partial regression coefficients for heifer's estimated transmitting ability (ETA) from first lactation records on dam's ETA from first or all lactation records, sire's milk Northeast Artificial Insemination Sire Comparison (NEAISC), and maternal grandsire's (MGS) milk NEAISC within deciles sorted by dam's ETA from all lactation milk records.

	Regression coefficients including dam's ETA from first lactations				Regression coefficients including dam's ETA from all lactations			
Decile[1]	Dam	Sire	MGS	R^2 [2]	Dam	Sire	MGS	R^2 [2]
1	.784	.475	−.128	.78	.403	.459	.037	.50
2	.811	.482	−.145	.76	.417	.468	.032	.53
3	.792	.480	−.144	.76	.388	.467	.040	.56
4	.784	.483	−.140	.77	.357	.470	.044	.57
5	.774	.477	−.133	.77	.307	.464	.056	.59
6	.754	.485	−.138	.77	.504	.472	.054	.60
7	.753	.483	−.140	.77	.386	.471	.042	.60
8	.735	.489	−.129	.78	.312	.479	.052	.62
9	.708	.487	−.123	.78	.349	.479	.053	.64
10	.684	.496	−.112	.81	.408	.486	.055	.68
All	.755	.484	−.135	.84	.391	.472	.048	.70
SE[3]	.0055	.0020	.0032		.0402	.0031	.0046	

[1] Heifer records with highest ranking dams for ETA from all lactation milk records are in decile 1.

[2] R^2 = Squared multiple correlation coefficient.

[3] SE = Largest standard error of the partial regression coefficients across deciles.

included dam's ETA from first lactation, the partial regression coefficient was small and negative. When the regression equation included the dam's ETA from all lactations, the partial regression coefficient was small and positive. This pattern suggests the weight for the MGS's proof compensates for the small weight for the dam's ETA from all lactations. This pattern agrees with results for predicting the proof of a bull from pedigree information (1, 2).

Squared multiple correlation coefficients (R^2) for milk before partitioning into deciles were .84 and .70 when regressions were on dam's ETA from first lactation and from all lactations. In general, regression on dam's ETA from first lactation gave R^2 that were an average of 20% larger than when regressions were on dam's ETA from all lactations. This agrees with (2). The multiple correlation coefficient was relatively constant regardless of type of sorting or decile when regression was on dam's ETA from first lactation for both milk and fat.

Effect of Decile on Dam's Partial Regression Coefficient

The partial regression coefficients in the first and tenth deciles (Tables 2 to 3) tended to be atypical of other deciles, which is probably a function of greater variation within the extreme deciles. Aside from general trends, weights for prediction of heifer's ETA from milk of first lactation were not affected by sorting records into deciles by dam's birthdate, dam's ETA from fat of first lactation, and by dam's ETA from fat of all lactations.

Sorting by dam's ETA from milk of all lactations caused slight downward trend of the weight for dam's ETA from milk in first lactation and fluctuations in deciles 4 to 9 for the weight for dam's ETA from milk of all lactations (Table 3) or dam's ETA from milk of first lactation. These fluctuations did not extend to weights for sire or maternal grandsire proofs with regression on either dam's ETA from milk of all lactations or dam's ETA from milk of first lactation (Table 3). Sorting by dam's ETA from milk in first lactation generated fluctuations of weights for dam's ETA from milk of first lactation. Weights associated with dam's ETA from milk of all lactations were essentially zero within all but the first and tenth deciles (Table 2). This indicates that once records have been classified roughly according to dam's ETA from milk of first lactation, no further information for prediction of heifer's ETA from milk in first lactation can be gained from dam's ETA from milk of all lactations. This result was unexpected.

When data were sorted by dam's ETA from milk of first lactation, weights for dam's ETA from milk of all lactations were consistently smaller than approximate theoretical weights across deciles. Consequently, preferential treatment of dams that had higher ETA from first lactation does not seem to be the reason that theoretical weights were so different from actual regressions on dam's ETA from all lactations. Preferential treatment had been suggested by other researchers when prediction of son's proof generated weights for dam's ETA from all lactations, which were smaller than expected (2,5,7,8). Similar results from prediction of heifer's ETA from fat of first lactation also suggest that preferential treatment cannot be the reason actual weights are smaller than theoretical weights for prediction of heifer ETA from first lactation. These results, however, cannot be extrapolated arbitrarily to state that preferential treatment is not the reason that weights to predict son's proof from dam's ETA from all lactations are smaller than those expected.

Effect of Deciles on Multiple Correlation Coefficients

Squared multiple correlation coefficients (Tables 2 to 3) were an average of 20% larger when regression was on dam's ETA from first lactation rather than on dam's ETA from all lactations. No trends associated with sorting into deciles were noted for R^2 when regression was on dam's ETA from first lactation.

Regression coefficients when the data were sorted by dam's birth date did not indicate any type of trend across deciles for R^2. When sorted by dam's all lactation milk, dam's fat of first lactation, and dam's fat from all lactations, R^2 showed a distinct increase as decile index increased from 1 to 10. This indicates that more variation of the model was explained when regressions were on ETAs which were smaller. After sorting by dam's ETA from milk of first lactation, R^2 from regressions on dam's ETA from milk of first lactation were only an average of 4% larger than from regressions on dam's ETA from milk of all lactations. Approximately

the same amount of variation was explained by either set of regressions.

CONCLUSIONS

Prediction of heifer breeding value as estimated by heifer ETA from first lactation should be based on dam's ETA from first lactation rather than dam's ETA from all lactations because: 1) regression on dam's ETA from first lactation results in weights closer to theoretical approximations than regressions on dam's ETA from all lactations; 2) regression on dam's ETA from all lactations within deciles stratified by dam's ETA from first lactation indicated that further information could not be gained from ETA from all lactations; and 3) more variation was explained for heifer's ETA from first lactation when regression was on dam's ETA from first lactation than when regression was on dam's ETA from all lactations.

Preferential treatment does not seem to be the reason that weights for dam's ETA from all lactations are smaller than expected. Time trends do not appear to affect estimation of dam weights.

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