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Genetic Analysis of Postnatal Mortality and Calving Traits in Iranian Holstein Herds Using Threshold-Linear Models

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ABSTRACT

This study was conducted to estimate the additive genetic components of calf mortality in the first month of age, calving difficulty, and birth weight in Holstein dairy cows in the central regions of Iran. The records comprised 61,200 calves born between 1990 and 2011 from 60 dairy herds. Different threshold-linear models in three groups of univariate, bivariate, and multivariate models were used. The frequency of calf mortality was 2.6%. Distribution of calving difficulty score was 65.12% in the first category (no assistance), 30.66% in the second, 3.12% in the third, and 1.1% in the fourth (major assistance). Averages of birth weight and dam age were 40.34 kg and 769.4 days, respectively. Direct Heritability estimation for calf mortality varied from 0.005 to 0.027. The estimated heritability for calving difficulty ranged from 0.032 to 0.050. Heritability for birth weight was estimated about 0.22. The results of this study showed that there were genetic variations for all traits. Although there was no strong additive genetic correlation between the traits, an environmental correlation between mortality and other traits was observed. Results suggested that implementation of threshold models for mortality trait was more favorable, but they were not reflected in genetic analysis of calving difficulty records. Furthermore, current findings indicated that benefit from the use of multi-traits models for genetic evaluation of postnatal mortality depended on the methodology (linear or threshold model) used for mortality trait.

Keywords: Birth weight, Calf mortality, Calving difficulty, Genetic parameters, Linear-Threshold models.

INTRODUCTION

Mortality of calves is one of the important health traits that could affect the revenue on dairy farms. Besides, it directly influences the number of replacement heifers in the herd, and the number of male calves for sale. Due to the economic and animal welfare considerations, mortality is one of the potential traits to include in dairy cattle breeding schemes (Hansen *et al*., 2003). Several studies have been reported on evaluation of the attitude toward risk factors for postnatal mortality (Waltner-Toews *et al*., 1986). The literature shows that calf health at the birth is highly associated with postnatal mortality in dairy herds (Heinrichs *et al*., 2001). A difficult parturition can substantially increase the calf's risk of death. Calving difficulty is one of the most important factors influencing calf health at the birth. It could increase respiratory difficulties and acidosis (Besser *et al*., 1990). Results from the first national study of US dairy heifer health also indicated that calving difficulty was associated with mortality within the first 21 days of life (Heinrichs *et al*., 1994). Wells *et al*. (1996) pointed out that up to 12% of dairy heifer mortality during the first 21 days of life could be prevented by decreasing calving difficulty. Other studies in dairy cattle showed mortality within 24 hours of birth

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was highly correlated (0.68 to 0.90) with calving difficulty (McGuirk, 1999). Birth weight is the most important factor in predicting calving difficulty. As for calving difficulty, Berger *et al*. (1992) indicated calves that are lighter and heavier than average tend to have more mortality within 24 hours of birth.

Currently, bulls are genetically evaluated based on the multi-trait models. Concerns when estimating heritability of discrete traits include the correct model to use. Many studies comparing multi-trait linear and linear-threshold models have been published for calving difficulty and stillbirth (e.g. Hansen *et al*., 2003). Theoretically, threshold models are the best alternative for linear model in analyzing discrete traits such as calving difficulty and mortality. Threshold models were firstly introduced in genetic evaluations by Wright (1934). Simulations studies revealed that the use of a threshold models could improve the genetic gains for such categorical traits (Meijering and Gianola, 1985). However, when fitting the models to the field data, only small differences in the ranking of sires have been found (Weller *et al*., 1989). Therefore, the efficiency of the procedure with field data still remains to be confirmed (Matilainen *et al*., 2009). It is supposed that a genetic evaluation of postnatal mortality can benefit from the use of correlated traits. Groen *et al*. (1998) recommended combining stillbirth, calving difficulty, gestation length, and birth weight in a multi-trait evaluation. Birth weight is a potential trait to include in genetic evaluation if it is associated with the other traits. Despite the importance of calf mortality in the first month of life, combined evaluation of mortality and calving trait is limited to mortality within 24 hours of birth and little information is available about the genetic evaluation of mortality within the first days of age with calving traits. This study was aimed to evaluate the incidence of calf mortality in the first month after birth, descriptive analysis of the traits related to mortality traits (such as calving difficulty and birth weight), its genetic aspects using linear and threshold models.

MATERIALS AND METHODS

Data

Records of 61,200 calves born to first-parity cows from 1990 to 2011 that had survived 24 hours after birth were collected from 60 dairy herds in the central parts of Iran. Records with unknown sire identification, calves with dams younger than 21 months of age at calving, calves with unknown calving difficulty, records of calf in the herds with less than 10 records per herd-year, and also sires with less than 10 records were excluded in final analysis. In addition, twins or malpresented calves were not included in this study, because the primary aim was to explore correctly the causes of death in single-born calves. The dataset used to investigate postnatal mortality during 1 to 30 days and calving difficulty contained 44,777 calves sired by 702 AI-bulls, and for birth weight of 29,248 calves sired by 625 AI bulls. Because only AI-sires were included, no confounding between the herds and sires was expected (Hansen *et al*., 2003).

Calf mortality was coded as 1 if a calf failed to survive and 0 if a calf survived in the first month. Calving difficulty was classed in 4 categories: 1= Calving without any assistance; 2= Calving with farmer assistance; 3= Calving with veterinary assistance, 4= Calving with difficulty and caesarean. Table 1 presents summary statistics for the continuous variables used in the final dataset, and Table 2 shows the incidences of calving difficulty and mortality by the sex.

Statistical Analysis

The statistical analysis consisted of two steps: (1) Regression analysis to determine the best model in order to predict mortality, calving difficulty, and birth weight, (2) Genetic analysis of postnatal mortality traits

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Table 1. Number of records and rate of mortality for all, female, and male calves in different class of calving difficulty.

Calving difficulty classes[a]	Number of records	Frequency of mortality (%)		
		Female	Male	All
1	34797	2.01	2.43	2.18
2	16383	2.58	3.41	3.10
3	1671	5.26	6.60	5.98
4	585	4.74	7.36	6.32

[a] 1= Unassisted calving; 2= Calving with farmer assistance; 3= Calving with veterinary assistance, 4= Calving with surgical assistance and caesarean.

Table 2. Simple statistics of continuous variables.

Variable	Sex[a]	Number	Mean	Standard deviation	Minimum	Maximum
Birth weight (Kg)	1	13730	41.58	4.48	25	55
	2	15518	39.24	4.14	25	55
Dam age (Day)	1	20453	771.38	74.16	641	1200
	2	24324	767.08	73.50	641	1199

[a] 1= Male, 2= Female.

to evaluate their genetic aspects using different threshold-linear models.

Regression Analysis

Linear regression was implemented for modeling birth weight. Logistic regression was used to model both mortality and calving difficulty. Logistic regression handles discrete variables well and gives the results that are easy to interpret. The analyses were done using SAS software (1999). In order to determine the best model, stepwise procedure was used. Odds Ratios (OR) were calculated to interpret results in logistic regression analysis.

To choose the best model in logistic regression, Akaike's Information Criterion (AIC) was used as the criterion to examine the model fits best (Akaike, 1973). The *AIC* includes a penalty for over parameterization. Therefore, a good balance between the fit and number of parameter estimates should be considered given the following:

$$AIC= -2\log(\text{likelihood})+2k,$$

Where, likelihood is the probability of data given a model, and k is the number of parameters. In the linear regression model, the best model was determined based on maximum adjusted R-square.

Genetic Analysis

The genetic parameters of postnatal mortality, calving difficulty, and birth weight were estimated and different models were examined. In addition, genetic correlations of postnatal mortality with other calving traits were estimated. Direct and maternal genetic variation for traits of interest were estimated using univariate linear and threshold models, which included correlated genetic effects of sires and maternal grandsires. In addition, univariate Threshold Sire Model (TSM) and Linear Sire Model (LSM) for the categorical nature of mortality and calving difficulty were fitted. Besides, LSM was also used for birth weight. Bivariate models as Linear-Linear Sire Model (LLSM), Linear-Threshold Sire Model (LTSM) and, Threshold-Threshold Sire Model (TTSM) were used for calving difficulty and mortality. Also, LLSM and LTSM were used for birth weight and

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mortality. Finally, multi-trait models containing mortality, calving difficulty, and birth weight traits by using different forms of linear and threshold models was fitted.

Genetic correlations between all traits were estimated using multivariate linear models based on Average Information Restricted Maximum Likelihood (AI-REML). Even though applying linear models to categorical traits does not support the assumptions of a linear model, it has been shown for sire models that genetic correlations are estimated with little bias (Gates *et al*., 1999). In dairy cattle breeding schemes, the accuracy of evaluations is usually expressed in terms of reliability, which is the squared correlation between the selection criterion and the true breeding value. Reliability was calculated by 1-(PEV/σ_G^2), where *PEV* and σ_G^2 are the prediction error variance as given by the diagonal term of the inverse of the information matrix (Henderson, 1975) and genetic variances, respectively.

All models for the mortality trait included the fixed effects of herd (1 to 60), season (1: Spring; 2: Summer; 3: Autumn, 4: Winter), sex (1: Male and 2: Female), calving ease (1 to 4 scores) and linear and quadratic effect of birth weight. The fixed effects based on *AIC* criteria for calving difficulty were herd-year-season, sex, birth weight (linear and quadratic forms), and dam age (only quadratic form). For the birth weight trait, the fixed effect of herd-year-season, sex, and linear and quadratic effects of dam age at calving were considered. In multivariate analysis of mortality with birth weight and calving difficulty, the effects of birth weight and calving difficulty were excluded, respectively. The major disadvantage of the threshold models is computational demand (Meijering and Gianola, 1985). For example, Bayesian model is easy to implement even for advanced models, but traditional threshold models for advanced models could be very complicated. Therefore, for computational ease in multi-trait evaluations, the regression effects were not considered.

Random effects in all models were sire additive genetic and residual components. In matrix notation, the following sire model was used:

$$y= X\beta+Zs+e,$$

Where, *y*= Vector of observations, *β*= Vector of fixed effects, *s*= Vector of random effects of sires, *X* and *Z*= Incidence matrices for fixed and random effects and, ***e***= Vector of random residual effects. In linear models, the random effects were assumed to be normally distributed: $s \sim N(0,\ G0 \otimes A)$ and $e \sim N(0,\ R_0 \otimes I)$, where G_0 and R_0 are variance–covariance matrices for random effects, *I* is an identity matrix and *A* is the numerator relationship matrix.

In addition, based on following models, the direct and maternal heritability for all traits were estimated as follows:

$$y= X\beta+ Z_1s+ Z_2mgs+e,$$

Where, *y, β, s, X,* Z_1 and *e* are as above, *mgs* is a vector of maternal grandsire effects and Z_2 is an incidence matrix relating the random effect of maternal grandsire effect. In linear models, the random effects were assumed to be normally distributed with the (co)variance:

$$\mathbf{Var}\begin{bmatrix} \mathbf{a}|\mathbf{A},\mathbf{G_O} \\ \mathbf{e}|\boldsymbol{\sigma}_\mathbf{e}^2 \end{bmatrix} = \begin{bmatrix} \mathbf{G_O}\ \mathbf{\ddot{A}}\ \mathbf{A} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{\sigma}_\mathbf{e}^2\mathbf{I} \end{bmatrix}$$ where $$\mathbf{G_O} = \begin{bmatrix} \sigma_{sire}^2 & \sigma_{sire,mgs}^2 \\ \sigma_{sire,mgs}^2 & \sigma_{mgs}^2 \end{bmatrix}$$ and *A* is the additive relationship matrix. The additive relationship matrix was created by tracing sire and dam paths as far as possible for bulls with records as a sire and maternal grandsire.

Estimates of (co)variance components in all models were obtained with AI-REML using the DMU-package (Madsen and Jensen, 2006).

For threshold analyses, generalized linear mixed model was used. The binomial and poison variance function and probit and log link function were applied to estimate (co)variance components for mortality and calving difficulty, respectively.

Estimations of heritability in the threshold models were calculated in accordance with the linear sire models and without restriction on residual variance. Genetic variance transmitted by the dam is not captured by the random component representing the sire and this variability should be represented in the residual variance. However, this is not possible to occur if the residual variance is set to be constant (Maia *et al*., 2013). Hence, the threshold model was performed with the free dispersion parameter. This approach is a case of quasi-likelihood modelling. Labouriau (2014) showed that parameters of such models are identifiable.

RESULTS AND DISCUSSION

Descriptive Results

Frequency of mortality in the first month of age in calves born to first parity cows was 2.6%, ranging from 3.01 to 2.27% in male and female calves, respectively. This study agrees with the findings in the previous studies (Hansen *et al*., 2003), that risk of dying is highest during the first days of life (Figure 1). Frequency of mortality obtained in the current study was close to an earlier report (Hansen *et al*., 2003). In a similar period, mortality rate of 3.23% in Danish Holstein cows was reported (Fuerst-Waltl and Sørensen, 2010). In another study, Simensen *et al*. (1982) showed 4% mortality (including stillbirth) in Norway. Ghavi Hossein-Zadeh *et al*. (2012) showed overall rate of 12.8% stillbirth in Iranian Buffaloes. However, in the current study the stillbirth was not considered.

Results showed usual distribution of calving difficulty; most of the records were in category 1 (65.12%) and few records in category 4 (1.1%). In general, percent of mortality in male was higher than female calves in all categories of calving difficulty (Table 1). Averages of birth weight and dam age in male and female calves were 41.58±4.48 and 39.2399±4.13 kg and 771.38±74.16 and 767.08±73.50 days, respectively (Table 2).

From 1991 to 2011, in contrast to calving difficulty, the mortality rate in the first month of life for the first calving cows had increased (Figures 2 and 3). It seemed that selection of proven bulls for reducing calving difficulty in recent years could not reduce the mortality rate. It is probably a result of existence of low genetic correlation between calving difficulty and mortality during first month of life.

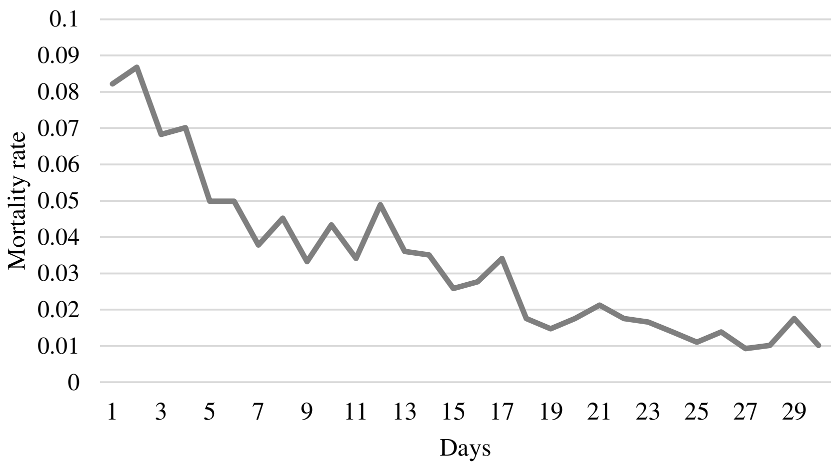

Figure 1. Proportion of dead calves from 1 to 30 days of age.

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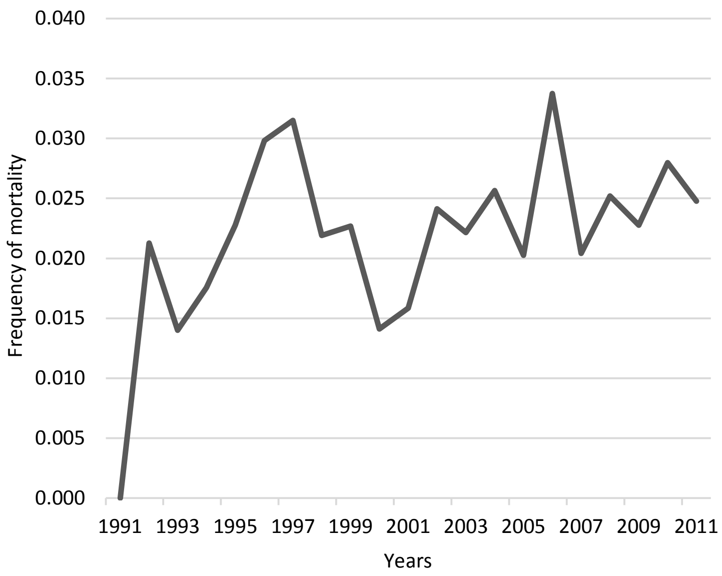

Figure 2. Mortality rates at first calving.

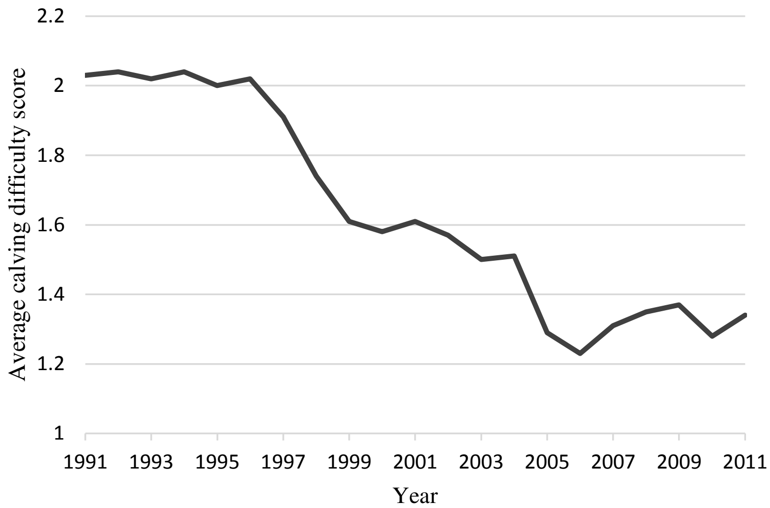

Figure 3. Average calving difficulty score at first calving**.**

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Regression Analysis

Using forward selection procedure in SAS, the best model (model 5, Table 3) based on AIC criterion for postnatal mortality was found to include the effects of herd, season, calving difficulty, sex, and linear and quadratic effects for birth weight of calf (AIC= 6,516). Table 3 shows few models investigated for predicting postnatal mortality. In model 1 containing the dam age as covariate and the effect of Herd-Year-Season (HYS), it was seen that HYS and dam age did not show significant effects. When the effect of HYS was separated in two effects of Herd-Year (HY) and season (model 3), it was shown that the both effects

Table 3. A comparison of eight different models for calf mortality.[a]

Effects	Model 1 [a]	Model 2 [b]	Model 3 [c]	Model 4 [d]	Model 5 [e]	Model 6 [f]
HYS	0.5181[g]	-	-	-	-	-
HY	-	-	<0.0001	-	-	-
Herd	-	-	-	<0.0001	<0.0001	-
Year	-	-	-	0.3467	-	0.0037
Season	-	-	<0.0001	<0.0001	<0.0001	<0.0001
Calving difficulty	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sex	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Age×Age	0.1260	-	-	-	-	0.0191
Age	0.1172	-	-	-	-	0.0096
Bw×Bw	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bw	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
AIC	6847.057	6717.913	6564.049	6522.500	6516.233	6659.070

[a] Includes Herd-Year-Season (HYS), calving difficulty, sex, dam age (linear and quadratic), and Birth weight (Bw) (linear and quadratic) effects; [b] Drops the HYS effect and dam age as linear and quadratic effects; [c] Also adds the Herd-Year (HY) and season effects; [d] Drops HY effect and adds both the herd and year effect, [e] Drops the year effect, [f] Includes effects of year, season, calving difficulty, sex, dam age (linear and quadratic), and birth weight (linear and quadratic). [g] *P*-value to test significance of the effect.

were significant (P< 0.0001, AIC= 6,564). When the effects of herd, year, and season were fitted individually in the model (model 4) interestingly the effect of year was no longer significant. It was also seen that when the effects of herd and year were fitted alone in the model (models 5 and 6) both of them were significant.

The best model for calving difficulty using logistic regression included the effects of HYS, sex, and linear and quadratic regression of dam age and birth weight (AIC= 37,662). Results of this study support the previous studies and show that birth weight not only influences the calving difficulty in linear form, but also it has nonlinear effect on calving difficulty. For the birth weight, the significant effects based on traditional regression procedure and adjusted R^2 were HYS, sex, and linear and quadratic regression of dam age.

Table 4 presents estimations of the odds ratio for significant factors in the postnatal mortality analysis. Effect of season on mortality was noticeable. Calves born in the autumn were more likely to die in the first month of age than calves born in the winter. The highest and lowest mortality rate was seen for calves born in the autumn and spring, respectively. Similar results were reported by Svensson *et al*. (2006) and Silva

Table 4. Odds Ratio (OR) estimates and interpretations for best postnatal mortality model (Model 5, Table 3).

Effects	Comparison	*OR*	Confidence interval (95%)
Season [a]	1 *vs*. 4	0.868	(0.691,1.092)
	2 *vs*. 4	0.977	(0.779,1.224)
	3 *vs*. 4	1.438	(1.175,1.759)
Sex [b]	1 *vs*. 2	1.495	(1.277,1.749)
Calving difficulty [c]	1 *vs*. 4	0.277	(0.174,0.439)
	2 *vs*. 4	0.315	(0.197,0.503)
	3 *vs*. 4	0.783	(0.465,1.319)

[a] 1= Spring; 2= Summer; 3= Autumn, 4= Winter. [b] 1= Male, 2= Female. [c] 1= Unassisted calving; 2= Calving with farmer assistance; 3= Calving with veterinary assistance, 4= Calving with surgical assistance and caesarean.

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del Río *et al*. (2007), who found that calf mortality rates were lower during warm months compared with cold months. Manfredi *et al*. (1991) showed that calving difficulty was reduced in the summer.

Calving difficulty was also found to increase the risk of death during the first month of life. Calving with difficulty and caesarean increased calf mortality rate by 78% compared to unassisted calving, given that all other factors were held constant. Similar results were reported by Ghavi Hossein-Zadeh (2014) who found that the odds of stillbirth was greater after severe dystocia (OR= 29.66). Male calves had a 50% greater chance of mortality than female calves after adjusting for all other factors. This may be attributed to the fact that male calves are usually heavier than females at the time of birth, which increases the chance of difficult calving for the cow.

Genetic Parameters

Estimates of variance components from univariate sire and maternal grand sire models are given in Tables 5 and 6, respectively. Sire additive genetic variance for calving difficulty using LSM and TSM were 0.0027±0.00065 and 0.0011±0.00029, respectively. These estimates for calving difficulty in maternal grandsire model were 0.0023±0.0006 and 0.0009±0.0003, respectively. The sire genetic component of mortality by LSM and TSM were 0.00003 and 0.00026, respectively. Hansen *et al*. (2003) reported that maternal genetic variations of postnatal mortality was very small and mostly could not be detected for

Table 5. Estimates of heritability (h^2), sire genetic (σ_s^2) and residual (σ_{res}^2) variances for mortality, calving difficulty and birth weight using univariate models.

Trait	Model	$h^2 \pm SE$	$\sigma_S^2 \pm SE$	$\sigma_{res}^2 \pm SE$
Mortality	LSM [a]	0.005±0.004	0.00003±0.00002	0.0238±0.00197
Calving difficulty		0.038±0.009	0.00270±0.00065	0.2857±0.00239
Birth weight		0.220±0.024	0.8307±0.0962	14.2485±0.1199
Mortality	TSM [b]	0.005±0.00	0.00026±0.00	0.2033±0.00
Calving difficulty		0.032±0.008	0.00111±0.00029	0.1401±0.00117

[a] Univariate Linear Sire Model, [b] Univariate Threshold Sire Model.

Table 6. Estimates of direct (h_d^2) and maternal heritability (h_m^2), sire genetic (σ_s^2), maternal grandsire genetic (σ_{mgs}^2) and residual (σ_{res}^2) variances for mortality, calving difficulty and birth weight using univariate maternal grandsire models.

TM [a]		LM [b]			Model/Trait
Calving difficulty	Mortality	Birth weight	Calving difficulty	Mortality	
0.023±0.0008	0.004±0.0	0.15 ±0.01	0.028±0.0.008	-	$h_d^2 \pm SE$
0.051±0.001	0.004±0.0	0.23±0.02	0.052±0.009	-	$h_m^2 \pm SE$
0.0009±0.0003	0.0002±0.0	0.86±0.106	0.0023 ±0.0006	0.00002±0.0001	$\sigma_S^2 \pm SE$
0.001±0.0003	0.00000004±0.0	0.43±0.056	0.0019 ±0.0005	0.00000002±0.0	$\sigma_{mgs}^2 \pm SE$
0.14±0.001	0.18±0.0	13.73±0.123	0.29 ±0.0026	0.02±0.0001	$\sigma_{res}^2 \pm SE$

[a] Univariate Threshold Model, [b] Univariate Linear Model,

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mortality even for early ages. In the current study, in agreement with previous study, maternal genetic variation of mortality was very small (Table 6). Genetic variability for mortality and calving difficulty were very low (Tables 5 and 6). Estimate of sire genetic component for birth weight using sire and maternal grandsire models were 0.00831 and 0.86, respectively.

Estimates of heritabilities using univariate sire models are shown in Table 5. Heritability estimates for mortality were 0.005 in linear and threshold sire models. Although the estimates from both threshold and linear models were similar, only estimate from threshold model was significant. In Iranian Holstein, Forutan *et al*. (2014) reported a heritability of about 0.005 using threshold and linear sire models for female calves in the period of days 1-30. In Danish Holstein, Hansen *et al*. (2003) reported a heritability of 0.0028 to 0.0014 using linear model for mortality in period of days 1-14 and 15-60, respectively. Fuerst-Waltl and Sørensen (2010) estimated a heritability of 0.017 and 0.082 in Danish Holstein, using linear and threshold models, respectively. The estimate of heritability for calving difficulty was low and significantly different from zero in both models. The estimated heritabilities for calving difficulty using linear (threshold) sire and maternal grandsire models were similar and in the range of the previous studies in Iranian Holstein (Eghbalsaied *et al*., 2012), French Montbeliarde (Ducrocq, 2000), and Italian Holstein-Frisian (Canevesi *et al*., 2003), where rather low heritabilities (0.03 to 0.1) were obtained.

Direct heritability values for birth weight were moderate (0.22±0.024 and 0.15±0.01) using univariate sire and maternal grand sire models, respectively (Tables 5 and 6). The birth weight heritability found in this study was in the range of previous studies. For example, in beef breeds heritability of birth weight ranged from 0.26 to 0.66 (Bennett and Gregory, 1996) while in dairy and dual breeds it ranged from 0.12 to 0.17 (Hagger and Hofer, 1990). Maternal heritability estimate based on univariate maternal grandsire model for birth weight was 0.23 (Table 6).

Heritability estimates obtained from models containing combination of mortality, calving difficulty, and birth weight were the same as those from bivariate models (Tables 7 and 8).

The selection of an appropriate model is critical to statistical inference from many types of empirical data. In this study, choice of most appropriate model for estimating the genetic components for each trait was done based on comparison between sire *EBV* reliabilities in different models. Estimation of reliabilities for calving difficulty by univariate linear and threshold sire models and linear and threshold maternal grandsire models were 0.25, 0.23, 0.13,

Table 7. Estimates of heritability (h^2) by bivariate model of mortality trait with calving difficulty and birth weight.

Bivariate model	$h^2 \pm SE$		$h^2 \pm SE$	
	Mortality	Calving difficulty	Mortality	Birth weight
LLSM [a]	0.014±0.004	0.050±0.008	0.014±0.004	0.224±0.025
TLSM [b]	0.026±0.005	0.050±0.008	0.027±0.005	0.223±0.025
LTSM [c]	0.014±0.004	0.044±0.008	-	-
TTSM [d]	0.026±0.005	0.044±0.008	-	-

[a] Linear-Linear Sire Model; [b] Threshold-Linear Sire Model; [c] Linear-Threshold Sire Model, and [d] Threshold-Threshold Sire Model.

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Table 8. Estimates of heritability (h^2) by multivariate model of mortality, calving difficulty and birth weight.

Multivariate model	$h^2 \pm SE$		
	Mortality	Calving difficulty	Birth weight
LLLSM [a]	0.014±0.004	0.050±0.008	0.211±0.023
TLLSM [b]	0.026±0.005	0.050±0.008	0.212±0.023
LTLSM [c]	0.014±0.004	0.045±0.0075	0.210±0.023
TTLSM [d]	0.026±0.005	0.044±0.0075	0.209±0.023

[a] Fully Linear Sire Model; [b] Threshold-Linear-Linear Sire Model; [c] Linear-Threshold-Linear Sire Model, and [d] Threshold-Threshold-Linear Sire Model.

and 0.11, respectively. In general, estimation of reliabilities for calving difficulty with univariate sire models were higher than maternal grandsire models, and in linear models was rather higher than threshold models. Even though threshold model is expected to estimate more accurate genetic parameters (Wright, 1934), this study in agreement with previous studies indicated that assumptions of threshold models did not satisfy calving difficulty traits (Eghbalsaied *et al*., 2012). Estimation of reliabilities for mortality by univariate threshold sire model was slightly greater than univariate linear model (0.24 *vs.* 0.23). Reliabilities estimated by maternal grandsire models for mortality were lower than sire models (0.24 *vs.* 0.04). Besides, reliabilities estimated by maternal grandsire models for birth weight were lower than sire models (0.30 *vs.* 0.53). Actually, using maternal grandsire models didn't improve the reliability of sire *EBVs* in current study. According to a simulation study by Janss and Foulley (1993), a bivariate model improved the accuracy of evaluation for categorical traits. As expected, reliabilities for calving difficulty by bivariate and multivariate models were higher (ranged 0.27-0.41) than univariate models. When bivariate model contained mortality in the threshold model and calving difficulty records in the linear model (TLSM in Table 7), the estimate of heritability and reliabilities for both traits were higher than other bivariate models. Similarly, when mortality was modeled in the threshold model compared to linear model with birth weight, higher heritability and reliabilities were obtained. As bivariate models, estimates of heritability and reliabilities by multivariate models were higher when mortality was in threshold model. In general, in both bivariate and multivariate models, when mortality was modeled in the linear model lower reliability compared to univariate models were obtained. It was seen that advantages of the threshold model for mortality were higher in multi-traits models than in univariate models.

The results of this study did not show significant genetic correlations between mortality and calving difficulty in all models considered (ranging from 0.08 to 0.15). The estimated residual correlation between the two traits was low (about 0.05±0.004) but significant in all the models. It also was true for correlation between mortality and birth weight. Genetic correlation between mortality and birth weight ranged from 0.006 to 0.1, in different models and also residual correlation between the two traits was very low (about -0.03±0.005). The genetic and residual correlation between calving difficulty and birth weight were 0.62 ±0.07 and 0.15±0.005, respectively. Therefore, the result suggests that non-genetic effects of calving difficulty and birth weight may influence mortality up to first month after birth.

CONCLUSIONS

Our results confirm that the mortality risk of Holstein dairy calves is relatively low during first month of life. Current results do not support the hypothesis that a genetic evaluation of categorical traits could be improved by using a threshold model in the case of calving difficulty. The type of methodology (linear or threshold) used for

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mortality trait determines the amount of benefits from multi-trait evaluation of mortality trait. Thus, including birth weight or calving difficulty as an additional indicator trait with postnatal mortality in threshold model could increase the *EBV* reliabilities.

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آنالیز ژنتیکی مرگ ومیر پس از تولد و صفات مربوط به زایش درگله‌های گاو شیری هلشتاین ایرانی با استفاده از مدل‌های خطی-آستانه‌ای

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چکیده

این مطالعه به منظور برآورد اجزاء ژنتیکی افزایشی مرگ ومیر گوساله‌ها در اولین ماه پس از تولد، سخت زایی و وزن تولد در گاوهای شیری هلشتاین در نواحی مرکزی کشور ایران انجام پذیرفت. اطلاعات شامل ۶۱۲۰۰ گوساله متولد شده در سال‌های ۱۹۹۰ تا ۲۰۱۱ در ۶۰ گله گاو شیری جمع‌آوری شد. مدل‌های خطی-آستانه‌ای متفاوتی در سه گروه تک صفتی، دو صفتی و سه صفتی مورد استفاده قرار گرفت. فراوانی مرگ ومیر گوساله‌ها ۲/۶درصد بود. توزیع نمره سخت‌زایی بصورت ۶۵/۱۲ درصد در اولین دسته (بدون کمک)، ۳۰/۶۶ درصد در دسته دوم، ۳/۱۲ درصد در سومین دسته و ۱/۱ درصد در چهارمین دسته(کمک فراوان) بود. متوسط وزن تولد و سن مادر به ترتیب ۴۰/۳۴ کیلوگرم و ۷۶۹/۴ روز بود. برآورد وراثت‌پذیری مستقیم برای مرگ ومیر گوساله‌ها بین ۰/۰۰۵ تا ۰/۰۲۷ متغیر بود. وراثت‌پذیری مستقیم برآورد شده برای صفت سخت‌زایی در دامنه ۰/۰۳۲ تا ۰/۰۵۰ قرار داشت. ضریب وراثت‌پذیری برای صفت وزن تولد در حدود۰/۲۲ برآورد شد. نتایج این مطالعه حاکی از وجود تنوع ژنتیکی برای تمام صفات مورد بررسی بود. اگرچه همبستگی ژنتیکی افزایشی قوی بین صفت مرگ ومیر و دیگر صفات مورد بررسی مشاهده نشد، اما همبستگی محیطی بین مرگ ومیر و دیگر صفات مشاهده شد. نتایج نشان می‌دهند که به کارگیری مدل‌های آستانه‌ای برای ارزیابی ژنتیکی صفت مرگ ومیر بر خلاف سخت‌زایی مطلوب‌تر هستند. بعلاوه نتایج حاضر نشان داد که سود حاصل از استفاده از مدل‌های چند صفتی برای ارزیابی ژنتیکی مرگ ومیر پس از تولد بستگی به نوع مدل مورد استفاده (مدل خطی یا آستانه‌ای) برای صفت مرگ ومیر دارد.

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