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Genetic Predisposition to Abortions Is Increasing in Iranian Holstein Cows

Research Article

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ABSTRACT

Abortion is an important trait with noticeable impacts on economic profit of dairy herds. This study was conducted to estimate variance components and genetic, environmental and phenotypic trends for abortions in Iranian Holstein Friesian cows. The data used were 247230 calving and abortion records of 84421 Holstein cows, collected during years 1991-2016, from 51 herds in Iran. Variance components and genetic parameters were estimated using a logit link function, fitting an animal mixed model by ASReml software. In this model, parity and milk yield were fixed, while direct additive genetic, herd-year-season and permanent environment effects were considered as random factors. Genetic, phenotypic and environmental trends were estimated as weighted regression coefficients of breeding values, phenotypic values and environmental deviations averages on birth year, respectively and the number of observations was considered as the weighting factor. Generally, abortion risk in the first parity was lower than the later parities and in autumn was lower than the other seasons. Abortion risk also increased by increase in milk yield level. Heritability and repeatability estimates for abortion were both 0.165 ± 0.010. A significant positive genetic trend (0.038 rate/year) and a significant negative environmental trend (-0.033 rate/year) were estimated for abortion, which indicated significant increase of genetic predisposition to abortions and improvement of environmental conditions to prevent abortion incidence. A significant positive phenotypic trend (0.002 rate/year) was also estimated, which showed overall increase of abortion rate during the studied years. Overall, it could be concluded that genetic predisposition to abortion is increasing in Iranian Holstein cows, but inclusion of abortion risk in bull proofs and selection indices may help to reduce abortion incidence and increase economic profit of dairy cattle industry.

KEY WORDS dairy cattle, heritability, parity, reproduction, season.

INTRODUCTION

Abortion, defined as "loss of pregnancy" between 42 and 260 days of gestation (Committee on Bovine Reproductive Nomenclature, 1972), is a limiting factor for dairy cattle industry. Abortions increase feeding and medical costs and number of services needed for pregnancy, and reduce milk production and potential number of replacement animals (Thurmond and Picasso, 1990). Some genetic factors and candidate genes have been known for their effects on abortion incidence (Pereza *et al.* 2017). In addition to genetic factors, some environmental factors, such as microbial and metabolic effects may also cause abortions and thus reduction of economic profitability of dairy cows. Abortion costs are not easily estimable, but most estimates are between 555 – 1000 USD (Thurmond and Picanso, 1990; Pfeiffer *et al.* 1997; Peter, 2000; De Vries, 2006). Generally, abortion cost is increased by gestation and lactation stages at conception (De Vries, 2011). In a study on Iranian Holstein cows, maximum abortion incidence was observed in the second parity (28.7%); the highest and lowest abortion rates were observed in mild and cold climates (16.0% *vs.* 14.5%, respectively) and the highest and lowest abortion rates (17.8 % and 13.5%, respectively) were observed in spring and autumn, respectively (Keshavarzi *et al.* 2016). Generally, an average of 3-5% abortion rate (>42 d of gestation) is expected for normal dairy herds (Hovingh, 2009). However, a wider spectrum of abortion rate, *e.g.* 1.5% (Carpenter *et al.* 2006) to 15.4% (Keshavarzi *et al.* 2017) could be found in literature.

Estimation of genetic, phenotypic and environmental trends provides an evaluation perspective for previous breeding and managerial strategies and estimates of variance components and genetic parameters are needed for construction of breeding programs in the future. Genetic trend is average change of breeding values and phenotypic trend is determined by both changes of genetic and environmental conditions (Abdoli *et al.* 2019). A hypothesis is that abortion rate in Holstein Friesian cattle is changing as the result of selection strategies. Evaluation of this hypothesis is necessary to optimize future breeding programs for Holstein Friesians. Up to this time, no study on genetic aspects of abortions in Iranian Holsteins was found in literature. However, some studies have been conducted on genetic aspects of calf stillbirth (Ghavi Hossein-Zadeh, 2014) and postnatal mortality (Forutan *et al.* 2016). The aim of this study was to estimate genetic, environmental and phenotypic trends for abortion rate, in Iranian Holstein-Friesian cattle.

MATERIALS AND METHODS

The data

The data were information of 247230 calving records of 84421 Holstein-Friesian cows, during 1991 to 2016, from 51 dairy herds, in Isfahan province of Iran. The loss of pregnancy between 42 and 260 days of gestation was defined as abortion. In the dataset, a total of 17465, 4029, 895 and 207 cows had 1, 2, 3 and 4+ abortion records, respectively. The pedigree file included 143078 animals and was analyzed using CFC software (Sargolzaei *et al.* 2006). General information of the pedigree structure is presented in Table 1.

Statistical analysis

The factors affecting pregnancy outcome (normal calving or abortion), including herd, year, season, parity and average daily milk yield were studied in a logistic model. The seasons were defined as four astronomical seasons: spring (Mar 21-Jun 21), summer (Jun 22-Sep 22), autumn (Sep 23 -Dec 21) and winter (Dec 22-Mar 20). The model was fitted using logistic procedure of SAS software (SAS, 2013). Variance components and breeding values were estimated using a logistic animal mixed model as follows:

$$\eta = Xb + Z_1a + Z_2h + Z_3p + e$$

Where:
η (Eta): vector containing the logit of pregnancy outcome;
b: vector of fixed effects, including parity (1 to 7) and the average daily milk yield in the parity as a covariate.
a, ***h***, ***p*** and ***e***: vectors of random effects, including direct additive genetic, herd-year-season (1435 levels), permanent environmental and residual effects, respectively.
$\boldsymbol{X}$, $\boldsymbol{Z_1}$, $\boldsymbol{Z_2}$ and $\boldsymbol{Z_3}$: incidence matrices relating observations to the corresponding effects.

The herd-year-season had 1435 levels and small observations in many subclasses and therefore was fitted as a random effect (Visscher and Goddard, 1993).

Variance components were estimated based on average information algorithm of restricted maximum likelihood (AI-REML) using ASReml version 2 (Gilmour *et al.* 2006).

Solutions of the vector **a** were considered as estimates of breeding values. Then, environmental deviations (E) were estimated as:

$$E = P - (\mu + EBV)$$

Where:
P: phenotypic value.
μ: overall mean.
EBV: estimate of breeding value.

Genetic, phenotypic and environmental trends were estimated as weighted regression coefficients of breeding value, phenotypic value and environmental deviation averages on birth year, respectively, where by the number of records per year was considered as the weighting factor. The regression coefficients were estimated using REG procedure of the SAS 9.4 (SAS, 2013).

RESULTS AND DISCUSSION

Fixed effects

All evaluated factors in the logistic model, including herd, year, season, parity, season and average daily milk yield, significantly (P<0.0001) affected pregnancy outcome (calving or abortion). Abortion frequencies and odds ratios in different levels of the classification factors, including parity, season and year are presented in the Table 2. Abortion rate was increased from the first to the second parity (9.08 to 13.76%) and then gradually decreased to the last (seventh) parity (10.09%).

Table 1 Summary of the pedigree information

Category	Number
Total animals	143708
Animals with records	84421
Sires	3719
Dams	86098
Animals with known sire and dam	124850
Animals with unknown sire	5857
Animals with unknown dam	2413
Animals with unknown sire and dam	9958
Animals with progeny	89816
Animals without progeny	53262
Inbred animals	105524
Average inbreeding coefficient	0.014

Table 2 Abortion frequencies, odds ratios and p values based on logistic model analysis, by parity, season and year in the studied population of Holstein Friesians

Factor	Levels	Total records	Normal calving	Abortion records	Abortion rate (%)	OR[1]	95% CL for OR[2]	P-value
Parity	1	88832	80767	8065	9.08	0.98	0.85-1.26	< 0.0001
	2	68998	59505	9493	13.76	1.59	1.31-1.93	
	3	43265	37714	5551	12.83	1.43	1.18-1.75	
	4	24408	21305	3103	12.71	1.45	1.19-1.78	
	5	12342	10826	1516	12.28	1.29	1.04-1.59	
	6	5600	4950	650	11.61	1.38	1.10-1.75	
	7	3785	3403	382	10.09	1.00	-	
Season	Spring	53909	46130	7779	14.43	1.33	1.27-1.40	< 0.0001
	Summer	69485	61439	8046	11.58	1.06	1.01-1.12	
	Autumn	66898	60415	6483	9.69	0.84	0.79-0.88	
	Winter	56938	50486	6452	11.33	1.00	-	
Year	1991-95	3026	2860	166	5.49	1.16	0.93-1.45	< 0.0001
	1996-00	7881	7290	591	7.50	1.22	1.05-1.42	
	2001-05	13244	12192	1052	7.94	1.70	1.52-1.90	
	2006-10	40005	36257	3748	9.37	2.13	2.00-2.27	
	2011-12	46858	41625	5233	11.17	1.76	1.67-1.87	
	2013-14	67240	58551	8689	12.92	1.81	1.72-1.91	
	2015-16	68976	59695	9281	13.46	1.00	-	

[1] Odds ratios of having a higher risk of abortion.
[2] 95% wald confidence limits for odds ratios.

Odds ratios showed lower risk of abortion in the first parity, compared to other parities (Table 2). The highest and lowest abortion frequencies (14.43% *vs.* 9.69%) were observed in spring and autumn, respectively. Odds ratios and 95% wald confidence limits of odds ratios showed significant lower risk of abortion in autumn, compared to other seasons (Table 2). Average abortion rate was obviously increased from the first to the last studied years (5.49% during 1991-95 to 13.46% during 2015-16). Odds ratios and their 95% wald confidence limits showed significant differences of abortion risk between some studied periods (Table 2). Abortion rate had a significant association with average daily milk yield (P<0.0001), whereby one kg higher daily milk yield increased abortion rate by 0.0235.

Variance components and genetic parameters

Estimates of variance components, heritability (h^2), repeatability (r) and coefficient of permanent environmental effects (pe^2), defined as ratio of permanent environmental to total phenotypic variances, are presented in the Table 3. Pregnancy outcome had a medium estimate of heritability (0.165±0.010), and the same estimate was also obtained for repeatability (0.165±0.010), while estimate of pe^2 was zero (Table 3).

Genetic, phenotypic and environmental trends

Estimates of genetic, environmental and phenotypic trends and their significance levels (P-values) are presented in Table 4.

Table 3 Estimates of variance components and genetic parameters ± standard errors (SE) for pregnancy outcome[1], in the studied population of Holstein Friesians

σ^2_a	σ^2_{pe}	σ^2_{hys}	σ^2_e	σ^2_p	h^2	pe^2	r
0.343±0.024	0.000±0.000	0.730±0.042	1.000±0.000	2.073±0.049	0.165±0.010	0.000±0.000	0.165±0.010

σ^2_a: additive genetic; σ^2_{pe}: permanent environmental; σ^2_e: herd-year-season; σ^2_{hys}: residual variances; σ^2_p: phenotypic variance; h^2: heritability; pe^2: coefficient of permanent environmental effects and r: repeatability.

Table 4 Estimates of genetic, environmental and phenotypic trends of abortions ± standard errors (SE), in the studied population of Holstein Friesians, during 1991-2016

Trend	Estimate ± SE	P-value
Genetic trend (rate/yr)	0.038±0.003	P < 0.0001
Environmental trend (rate/yr)	-0.033±0.003	P < 0.0001
Phenotypic trend (rate/yr)	0.002±0.001	P < 0.0023

A positive significant genetic trend (0.038±0.003 rate/year) was estimated for abortion which indicated increase of genetic predisposition to abortion over the studied period. The estimate of environmental trend was negative and significant (-0.033±0.003 rate/year), meaning a general improvement of environmental conditions for prevention of abortion in the studied population. The genetic and environmental trends were well fitted by linear regression models with high coefficients of determination (0.87 and 0.81, respectively), (Figure 1). Phenotypic trend of abortions was positive and significant (0.002±0.001 rate/year), which shows a general increase of abortion incidence during the studied period (Table 4, Figure 1).

In the present study, abortion rate varied from 5.49 to 13.46%, during different time sections (Table 2). This range is higher than the reported rates of 2% in 54 dairy farms in England (Murray, 1990) and 1.5% in Denmark (Carpenter *et al.* 2006), near to 10.8% in 10 Holstein herds in the northwestern United States (Forar *et al.* 1996) and 9.8% in three commercial dairy farms in California (Ettema and Santos, 2004) and lower than 15.4% in some Iranian industrial dairy farms (Keshavarzi *et al.* 2017).

Economic profit in any dairy cattle enterprise depends on several factors such as milk traits, feed efficiency and reproduction traits. Adjustment of environmental factors is a general applicable method to improve animal efficiency and profit (Zamani *et al.* 2011). Some efficiency criteria are highly correlated with production traits and thus could be improved via selection on production traits (Zamani *et al.* 2008), while independent traits would not be easily improved by indirect selection (Zamani, 2017). Reproductive performance is another important factor, with noticeable impacts on profitability, which cannot be easily improved by direct selection. Because most of the reproduction traits in both dairy and beef cattle tend to be lowly heritable, from 0.02 to 0.04 (Berry *et al.* 2014).

Abortion in dairy cattle is a complex trait and its incidence is influenced by several factors, either infectious, including bacterial, mycotic and viral causes (Peter, 2000) or non-infectious, such as herd, parity, pregnancy stage, calving month or season, days in milk, previous abortion and mastitis (Keshavarzi *et al.* 2016; Keshavarzi *et al.* 2017). Increase of abortion risk from the first to later parities in the present study agrees with previous studies (Keshavarzi *et al.* 2017). Positive association of milk yield and abortion rate is also supported by Norman *et al.* (2012). A main reason of unfavorable correlation between milk yield and abortion rate is that high producing cows are generally in negative energy balance which may be associated with a higher incidence of metabolic disorders, impaired fertility, and other health problems (Zamani *et al.* 2008). As it could be seen in the Table 3, a zero pe^2 and equal heritability and repeatability were estimated for pregnancy outcome. This result indicates that environmental factors affecting abortion are mainly temporary and do not have any permanent effect on the cows. In other words, abortion is influenced by specific temporary environmental effects (such as metabolic disorders, diseases and so on) rather than permanent environmental factors.

Pandey *et al.* (2016) reported a low estimate of heritability for abortions (0.031) in a population of crossbred cows. In a Hungarian Holstein population, heritability estimates for abortion, within 60 days in first, second and third parties were 0.12, 0.15 and 0.28, respectively and 0.24 for the pooled records (Amin *et al.* 2000). The estimate of heritability for abortion in the present study (0.165) agrees with the estimates reported by Amin *et al.* (2000). The observed variations of the heritability estimates can be attributed to possible differences in genetic and environmental conditions of the studied populations and the analysis methods. For example, heritability in the Pandey *et al.* (2016) study was estimated from paternal half sib correlation method. On the other hand, a population with different herds and managerial conditions would have a lower estimate of heritability. Medium estimates of heritability for abortion in the present study (0.165) indicates medium impact of additive genetic effects on abortion and possibility of genetic selection for this trait.

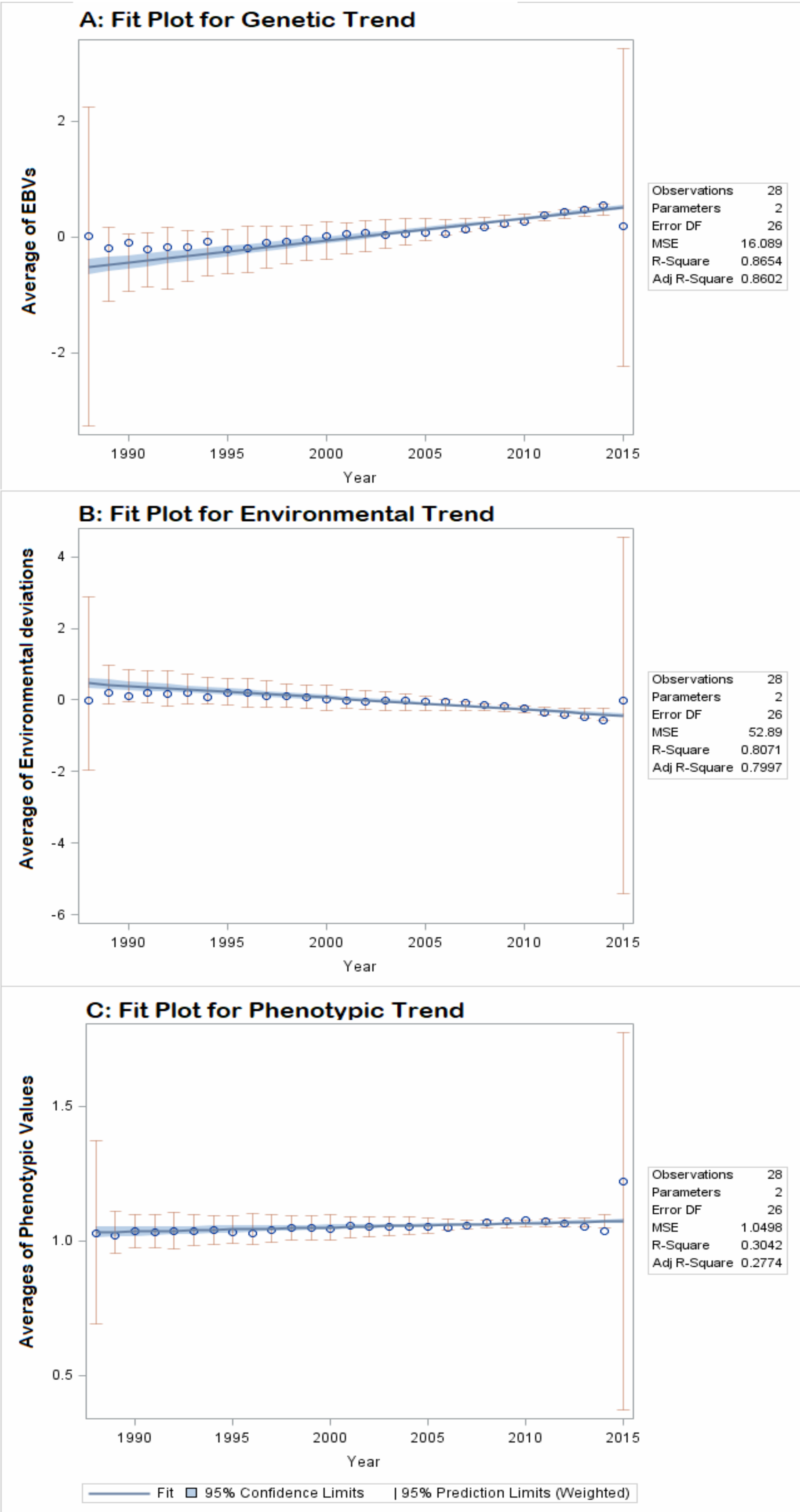

Figure 1 Genetic, environmental and phenotypic trends of abortion rate in the studied population of Holstein Friesians, during 1991-2016
A: genetic trend; B: environmental trend and C: phenotypic trend

Significant positive genetic trend of abortions (0.038 rate/year) indicated significant increase of genetic predisposition to abortions in the studied population or possibly global Holstein Friesian population. Because, most Holstein sub-populations are genetically similar and genetically linked together, whereby the effective size of global Holstein population is approximately 100 (Hill, 2010). Thus, possible differences of production or reproduction traits, between Holstein sub-populations, are mainly due to some differences in environmental effects, such as climate, nutrition, management and so on. Therefore, estimation of genetic trend for an important economic trait in a sub-population, can present a perspective for global Holstein population.

Positive genetic trend of abortions indicated lack of attention to abortions in previous breeding programs. Increase of genetic predisposition to abortion is an unfavorable result of selection on milk yield traits, because milk production traits, commonly have negative genetic correlations with health and fertility traits (Pryce *et al.* 1997; Roxström *et al.* 2001). Regarding medium heritability of abortion, decrease of abortion rate would be expectable by genetic selection on abortion, or inclusion of abortion risk in selection indices. Currently the sperm catalogues do not have any information about breeding values for abortion. It seems that the bulls should be evaluated for abortion risk and their breeding values, both for abortion risk in sire and daughters, similar to those for calving ease, should be reported in bull proofs.

A negative and significant environmental trend (-0.033 rate/year) was estimated during the studied period. Environmental trend of abortions could be attributed to different situations of various infectious agents (bacteria, viruses, protozoa and fungi), non-infectious agents (such as nutritional factors, management, genetic disorders) and other unknown factors (Peter, 2000) over the studied trajectory. Nutritional supplementation and other aspects of feeding, such as energy or protein levels in the diet are also considered as putative causes of the pregnancy outcome (Forar *et al.* 1996). Abortion is also affected by infectious factors such as *Neospora* (Alves *et al.* 1996) and bovine viral diarrhea (Carpenter *et al.* 2006). Other factors, such as herd conditions, parity number, pregnancy stage, month or season, days in milk and mastitis are considered as non-infectious factors affecting abortion rate (Keshavarzi *et al.* 2016; Keshavarzi *et al.* 2017). Negative environmental trend of abortions in the studied population indicated improvement of environmental factors preventing abortions. This improvement is due to noticeable advances in nutritional, medical and other environmental conditions in past decades.

Despite significant improvement of environmental conditions, a significant positive estimate of phenotypic trend (0.002 rate/year or 0.2 %/year), shows significant increase of abortion rate during the studied period. This phenotypic trend means 5.2% increase of abortion incidence during 26 years, which is lower than the actual difference of abortion rates between initial and last year sections (7.97%), as presented in the Table 2. This difference (5.2% *vs.* 7.97% increase of abortion) is due to different methods used for calculation. Because, the phenotypic trend (0.002 rate/year) was estimated by a weighted regression model, whereby initial years records had lower weights due to smaller sample sizes.

CONCLUSION

Generally, abortions risk in the first parity was lower than the later parities and in autumn lower than the other seasons. Abortion risk also was increased by increase of milk yield level. Genetic predisposition to abortion is increasing in Iranian Holstein population. However, improvement of environmental conditions, to some extent, deactivates the increase of genetic predisposition to abortion. Based on medium heritability of pregnancy outcome, reduction of abortion rate is expectable by direct selection or inclusion of pregnancy outcome in selection indices. Estimates of breeding values for abortion risk in sires and daughters should be reported in bull proofs.

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