Impact of birth weight of Iranian Holstein calves on their future milk production and reproductive traits

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Abstract The objective of this study was to investigate the effect of birth weight (BW) on future milk production and reproductive performance in Iranian Holstein cattle. Records of Holstein cows between 1967 and 2010 were obtained from the Animal Breeding Center of Iran. Birth weights within each herd were grouped into five categories based on the standard normal distribution curves ($z \leq -0.8416$, $-0.8416 < z \leq -0.2533$, $-0.2533 < z \leq 0.2533$, $0.2533 < z \leq 0.8416$, $0.8416 < z$). The results indicated that BW significantly affected ($P < 0.001$) the lactation parameters (e.g. milk yield, protein yield, fat yield), age at first calving (AFC), interval between calving to first insemination (ICFI), calving intervals (CI), calving ease (CE), and first service to conception length (FSTC) during the first three lactation periods. The BW positively affected the lactation performance, but had a negative effect on the reproductive performance. Increase in BW was unexpectedly associated with increased dystocia. The present study indicated that BW could impact economical traits of Holstein dairy cattle and need to be considered in breeding programs.

Keywords: birth weight, milk production, reproduction, Iranian Holstein

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Introduction

Calving is the most important functional trait in dairy cows due to its subsequent effects on economical traits (Dematawena and Berger, 1997 ; Bastin et al., 2010). Repeoductive problems can lead to calve mortality, metabolic disorders, and growth depression (Olson et al., 2009). Birth weight is the first recorded trait after birth which is influnced by several factors, especially the age and weight of the dam. BW is highly heritable in dairy cows (Andersen and Plum, 1965), while the genetics potential of parents contribute to about 60% of phenotypic variations in calf size (Roche et al., 2009).

Birth wieght is positively correlated with maternal size (Dawson et al., 1947; Singh et al., 1970; Swali and Wathes, 2006). The ratio of calf weight to mother weight has a positive correlation with BW (Johanson and Berger, 2003). In addition, a positive correlation has been reported for weight at maturity and BW (Lamb and Barker, 1975). It has been demonstrated that larger cows give birth to larger calves (Lykins, et al., 2000; Sieber et al., 1989; Swali and Wathes, 2006), where every 100 kg increases in maternal weight will result in 0.9 kg increase in calf weight (Nelson and Beavers, 1982). The correlation and heritability of the maternal weight and BW have been estimated at 0.22 to 0.34 (Linden et al., 2009) and 0.11 to 0.42 (Andersen and Plum, 1965), respectivey. A positive correlation between BW and daily gain (Chew et al., 1981; Dawson *et al.*, 1947), and final weight (Boligon *et al.*, 2010) has also been reported. The specific range of BW is highly correlated with the animal functionality (Pabst *et al.*, 1977), and in general, the heavier calves at birth will perform better compared to smaller calves (Lamb and Barker, 1975).

Limited information has been reported on the BW and calf birth weight of Iranian Holstein cows (Ghiyasi et al., 2011). Atashi *et al.* (2012) suggested that genetic selection for lowering the calf birth weight could be one means of reducing the incidence of dystocia in dairy cattle. The aim of this study was to investigate the impact of BW on the subsequent calf production and its effects on calf reproduction traits in future.

Materials and Methods

The records collected by the Animal Breeding Center (Karaj, Iran) on milk yield, fat yield and protein yield in the first, second and third lactation periods (between 1967 and 2010) were corrected for 100-d, 305-d production and twice daily milking. The outlier records were excluded based on arbitrary ranges for the first (18-40 months of age), second (30-60 months of age) and third (40-80 months of age) lactation periods. Reproductive traits were calculated based on recorded dates for each female (Jamrozik et al., 2005a,b). The studied reproductive traits were age at the first calving (AFC), interval between calving to first insemination (ICFI), calving interval (CI), calving ease (CE), and first service to conception length (FSTC). The traits were calculated for the first three lactations. Calving ease was subjectively scored in five classes (1 = no problem, 2 = slight problem, 3 = needed assistance, 4 = considerable force and 5 = extreme difficulty) and all observations for twins and abortions were removed from the analysis. The same dataset were used previously (Ghoreyshi et al., 2013) where the effect of calf birth weight on the performance of her dam was determined; however, in the present study, the impact of birth weight of the calf on the her performance at maturity was investigated.

For determination of the effect of BW on performance and reproductive traits, the herds with less than 100 observations were eliminated. The BW within each herd was grouped into five categories based on the estimated standard normal distribution curves as follow: $z \leq -0.8416$, $-0.8416 < z \leq -0.2533$, $-0.2533 < z \leq 0.2533$, $0.2533 < z \leq 0.8416$, $0.8416 < z$. The means of BW (± SD) in each group were 33.93 (3.37), 39.02 (0.87), 40.84 (0.83), 43.53 (1.05), and 47.91 (3.04) for the first parity, 33.94 (3.6), 39.12 (0.86), 40.93 (0.84), 43.65 (1.03), and 48.65 (3.52) for the second parity, and 34.01 (3.59), 39.16 (0.85), 40.95 (0.84), 43.7 (1.02) and 48.93 (3.71) for the third parity. The single trait animal model for analyzing performance and reproduction traits was as follows:

$$y_{ijk}=\mu+HYS_i+group_j+\beta_1 AGE_k+a_k+e_{ijk} \quad (1)$$

where y_{ijk} is the record k from MY, FY, PY, AFC, ICFI, CI, and FSTC; μ_i is the overall mean; HYS_i is the effect of herd-year-season at calving; $group_j$ is the grouping effect of BW in each herd; AGE_k is the effect of age at calving; β_i is the linear regression coefficient on age at calving; a_k is direct additive genetics random effect; e_{ijk} is the residual random effect. A non-genetic additional random effect of service sire was also added to the model for estimation of FSTC.

Table 1. Summary of the data structure for production and reproductive traits in the first, second, and third parities

Trait*	Parity	Number	Mean (SD)	Minimum	Maximum
	1	177051	2420.0 (507.2)	340.1	6115.0
MY 100	2	128325	3068.0 (674.5)	347.1	6208.0
	3	78912	3267.0 (726.6)	363.4	6463.0
	1	177051	7433.0 (1621.9)	1502.0	19520.0
MY 305	2	131456	8184.0 (1932.5)	1531.0	19670.0
	3	81058	8503.0(2048.5)	1606.0	18600.0
	1	177051	202.7 (59.0)	37.5	678.1
FY 305	2	112681	263.5 (70.8)	38.1	750.8
	3	69449	275.2 (75.1)	48.8	710.4
	1	177051	233.0 (57.9)	46.1	752.0
PY 305	2	78123	263.0 (69.8)	49.9	879.2
	3	50034	270.7 (57.2)	55.2	887.4
	1	140116	120.5 (64.8)	22.0	299.0
ICFI	2	101210	119.7 (64.4)	22.0	299.0
	3	62743	119.1 (63.7)	22.0	299.0
	1	135621	28.1 (31.1)	0.0	402.0
FSTC	2	81618	32.8 (42.1)	0.0	402.0
	3	47733	35.6 (43.2)	0.0	402.0
	1	226820	465.7 (138.6)	281.0	700.0
CI	2	99648	444.9(137.1)	281.0	700.0
	3	58849	438.1 (135.9)	281.0	700.0
	1	195354	1.3 (0.7)	1.0	5.0
CE	2	175281	1.2 (0.6)	1.0	5.0
	3	88243	1.2 (0.6)	1.0	5.0
AFC	-	177051	25.9 (0.5)	18.0	40.0

*MY= Milk yield; FY= Fat yield; PY= Protein yield; ICFI= Interval between calving and first service; FSTC= Interval between first service to conception; CI= Calving interval; CE= Calving ease; AFC= Age at first calving.

Table 2. Effects of birth weight grouping on production traits

Trait*	Parity	Error DF	F	P-Value	Power
	1	161024	45.51	< 0.001	> 0.999
MY 100	2	112642	30.51	< 0.001	> 0.999
	3	66725	10.12	< 0.001	> 0.999
	1	161024	58.27	< 0.001	> 0.999
MY 305	2	115484	21.10	< 0.001	> 0.999
	3	68665	11.18	< 0.001	> 0.999
	1	161024	22.22	< 0.001	> 0.999
FY 305	2	98217	18.94	< 0.001	> 0.999
	3	58305	9.18	< 0.001	> 0.999
	1	161024	58.27	< 0.001	> 0.999
PY 305	2	69265	18.58	< 0.001	> 0.999
	3	42773	7.68	< 0.001	> 0.999

*MY= Milk yield; FY= Fat yield; PY= Protein yield

The statistical model for calving ease was as follows:

$$y_{ijklmn}=\mu+group_j+HYS_i+SEX_k+\beta_1 AGE_m+a_m+S_n+e_{ijklmn} \quad (2)$$

where y_{ijklmn} is the record m for CE; μ is the overall mean; $group_i$ is the grouping effect of BW in each herd; HYS_i is the effect of herd-year-season at calving; SEX_k is the calf gender; AGE_m is the effect of age at calving; β_1 is the linear regression coefficient on age at calving; a_m is the direct additive genetics random effect; S_n is the additional random effect of service sire; e_{ijklmn} is the residual random effect.

The animal models were analyzed using the ASReml software (Gilmour, 2000) and the power of hypothesis test was performed with PWR package in R program (Champely, 2006).

Results and Discussion

The estimated results for analysis of variance and probability of effects differences between BW groups for production traits are given in Table 2. The effects of BW grouping were significant on the production traits ($P < 0.001$). The power of test for all analyses was more than 0.999 suggesting very low probability of the type II errors. Therefore, the low P-value andvery high power prove the profound effects of BW grouping on production traits.

The effects of BW grouping and corresponding standard errors for production traits are shown in Tables 3 and 4. The minimum value for BW grouping estimated in the first group of weight category showed that the cows with lower BW had lower production than other groups during the first three calving periods. The maximum value for BW grouping of milk yield was observed in the fifth group during the first and second parities. A positive trend for production traits was observed with increasing weight of cows at birth. Pabst *et al.* (1977) similarly reported that BW has a positive relationship with performance. In other words, the calves with higher BW will have higher growth rate than those with lower BW (Boligon et al., 2010; Chew et al., 1981; Coffey et al., 2006; Dawson et al., 1947).

Furthermore, those calves with higher BW also had higher persistency than low-BW calves (Chew et al., 1981; Lamb and Barker, 1975; Singh et al., 1970).

Table 3. The value of birth weight grouping and standard errors for milk yield

Group	Milk yield 100-d			Milk yield 305-d		
	First Parity	Second Parity	Third Parity	First Parity	Second Parity	Third Parity
1	-28.55 (4.13)	-31.03 (5.30)	-36.00 (7.45)	-87.30 (10.33)	-84.39 (15.31)	-102.90 (21.63)
2	0.00	0.00	-1.61 (6.72)	0.00	0.00	13.03 (20.09)
3	8.89 (3.76)	7.32 (4.88)	0.00	22.13 (9.40)	13.02 (14.11)	0.00
4	19.00 (3.89)	18.20 (5.00)	9.25 (7.02)	48.65 (9.75)	45.17 (14.46)	36.83 (20.38)
5	25.41 (4.18)	26.11 (5.34)	6.14 (7.30)	66.30 (10.48)	43.12 (15.45)	18.67 (21.20)

Table 4. The value of birth weight grouping and standard errors for fat and protein yields

Group	Fat yield 305-d			Protein yield 305-d		
	First Parity	Second Parity	Third Parity	First Parity	Second Parity	Third Parity
1	-2.78 (0.51)	-3.13 (0.54)	-3.68 (0.77)	-87.30(10.33)	-2.74(0.57)	-2.96(0.78)
2	0.00	0.00	0.05(0.72)	0.00	0.00	0.22(0.73)
3	-0.17 (0.47)	-0.27 (0.50)	0.00	22.13(9.40)	0.56(0.53)	0.00
4	0.44 (0.48)	0.50 (0.51)	0.49 (0.73)	48.65(9.75)	1.81(0.54)	1.31(0.73)
5	-2.34 (0.52)	1.64 (0.54)	0.50 (0.75)	66.30(10.48)	1.62(0.57)	0.52(0.77)

The results of the analysis of variance and power of test for reproductive traits are shown in Table 5. The effect of BW grouping on AFC, ICFI, and CE during the first three lactation periods was significant ($P < 0.001$). Although this effect was not significant for FSTC and CI in the third lactation, these traits were significantly affected by BW grouping in the first and second lactations. The estimated power of test was greater than 0.999 for all reproductive traits, suggesting high reliability of the statistical results at given confidence level.

The effect of BW grouping and standard error for estimated reproductive traits are given in Tables 6 and 7. The value of BW grouping indicated increases in reproductive traits with increasing weight between groups. The results showed that minimum ICFI was observed in the first BW group, and that it increases with BW value. At first lactation, the minimum and maximum values of BW grouping for CI were attributed to the first (-10.22) and fifth (8.56) groups, respectively. However, this trend was reversed in the second and third lactations. In other words, females with higher BW will have a longer CI, which might be because of enhanced embryo development (Laster et al., 1973; Lykins, et al., 2000).

The FSTC in third parity was not affected by BW grouping and there was no specific trend for this trait. The largest impact of BW grouping on calf performance at maturity was attributed to the CI in the first and second lactations. The above results confirmed that heavier cows have a longer gestation period than light cows (Laster et al., 1973; Lykins, et al., 2000). Also, it has been reported that low weight in the earlier lactations might reduce the chance of pregnancy at the first insemination due to low potential of the individual for providing energy demands of ovarian activity and estrous expression (Bastin et al., 2010). Nelson and Beavers (1982) reported a reduced conception rate in the light calves compared to heavier ones which is consistent with the result of this study. The analysis of CE showed that BW grouping had a significant effect on dystocia (Table 7), where the higher BW resulted in

Table 5. Effect of birth weight grouping on reproductive traits

Trait[*]	Parity	DF	F	P-Value	Power
ICFI	1	126885	7.45	< 0.001	> 0.999
	2	90383	7.20	< 0.001	> 0.999
	3	54747	4.47	0.001	> 0.999
FSTC	1	127034	9.03	< 0.001	> 0.999
	2	75631	4.63	< 0.001	> 0.999
	3	43759	1.48	0.21	> 0.999
CI	1	196997	102.84	< 0.001	> 0.999
	2	84862	3.23	<0.050	> 0.999
	3	47853	1.57	0.18	> 0.999
CE	1	211626	1324.53	< 0.001	> 0.999
	2	163278	548.06	< 0.001	> 0.999
	3	122917	766.76	< 0.001	> 0.999
AFC	-	161024	99.50	< 0.001	> 0.999

[*] ICFI= Interval between calving to first service; FSTC= Interval between first service to conception; CI= Calving interval; CE= Calving ease; AFC= Age at first calving.

Table 6. The value of birth weight grouping and standard error for ICFI and CI traits

Groups	ICFI			CI		
	First Parity	Second Parity	Third Parity	First Parity	Second Parity	Third Parity
1	-1.03 (0.62)	-1.00 (0.73)	-3.90 (1.03)	-10.22 (0.98)	0.50 (1.45)	3.24 (1.91)
2	-0.77 (0.57)	-0.05 (0.67)	-3.03 (0.97)	-6.00 (0.88)	1.04 (1.33)	2.59 (1.76)
3	0.00	0.00	-2.34 (0.93)	0.00	0.00	0.00
4	0.75 (0.57)	1.52 (0.68)	-2.30 (0.96)	3.51 (0.9)	-1.54 (1.36)	0.26 (1.80)
5	2.41 (0.61)	3.52 (0.71)	0.00	8.56 (0.96)	-3.17 (1.42)	-0.68 (1.86)

ICFI= Interval between calving to first service; CI= Calving interval.

higher dystocia. This unexpected result needs further investigation. The CE was regularly increased with weight grouping in the first and third parities. However, for the second group it increased at the second parity. Maximum values of BW grouping in the fifth group were 0.044, 0.15, and 0.025 for the first, second, and third lactations, respectively. However, Laster (1974), Balcerzak et al., (1989), Thompson et al., (1981) and Atashi et al., (2012) reported that increased calve birth weight was associated with increased dystocia. The main cause of dystocia in small cows is the large size of calf at birth; therefore, maternal age at calving may be an important factor in the occurrence of dystocia through the size of mother (Morris et al., 1986). In the present study, the effect of BW grouping on AFC was significant (P < 0.001) with increasing BW reducing the age at puberty, resulting in earlier manifestation of economical traits. Similar findings were reported by Johanson and Berger (2003), Boligon et al., (2010) and Lamb and Barker (1975).

Conclusions

The results of this research showed that birth weight is a significant parameter in calf performance after maturity and most of the reproductive traits are related to this trait. Therefore, birth weight should be considered as an important trait in dairy cattle breeding programs.

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Table 7. The value of birth weight grouping and standard error for FSTC, CE and AFC

Groups	FSTC			CE			AFC
	First Parity	Second parity	Third Parity	First Parity	Second Parity	Third Parity	
1	-1.02 (0.53)	-0.04 (0.67)	-1.21 (0.99)	-0.014 (0.005)	0.016 (0.004)	-0.011 (0.006)	0.19 (0.02)
2	0.00	0.48 (0.61)	-0.07 (0.95)	-0.004 (0.005)	-0.004 (0.003)	-0.007 (0.005)	0.00
3	-0.18 (0.48)	0.00	-1.41 (0.9)	0.00	0.00	0.00	-0.09 (0.02)
4	0.53 (0.50)	0.35 (0.63)	-1.57 (0.94)	0.020 (0.004)	0.037 (0.003)	0.011 (0.006)	-0.18 (0.02)
5	2.34 (0.53)	2.55 (0.66)	0.00	0.044 (0.005)	0.15 (0.37)	0.025 (0.006)	-0.22 (0.02)

FSTC= Interval between first service to conception; CE=Calving ease; AFC= Age at first calving.

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